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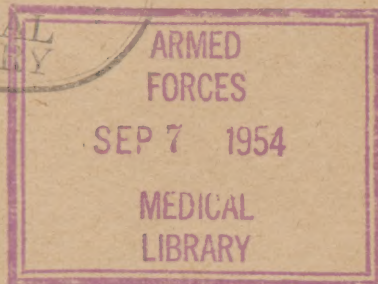
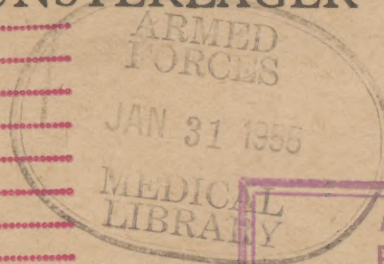
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CHEMICAL WARFARE INSTALLATIONS IN THE MUNSTERLAGER AREA

Exec	Def
ESS	Med
ABJ	NP
ESR	Surg
Trop	Recen
VD	Vet
Lab	Oper
San	Train
EE	Hosp
Civ-Nutr	Supp
	Control
	Med Stat
	Hist
	Res Dev



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Investigation of Chemical Warfare
Installations in the Munsterlager
Area, including Raubkammer.

Reported by

W/C. A. K. MILLS,

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CIOS Item 8
Chemical Warfare

COMBINED INTELLIGENCE OBJECTIVES SUB-COMMITTEE
G-2 Division, SHAEF (Rear) APO 413

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Investigation of Chemical Warfare Installations
in the Munsterlager area, including Raubkammer

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Period of investigation :-

23rd April to 3rd June, 1945.

1. Introduction

The Munsterlager target was intended to embrace all chemical warfare installations on the Lüneberger Heide, a tract of land situated between Lüneberg and Celle and centred roughly about the town of Munster. On investigation it was found to include the following separate installations,

1. Heeresversuchsstelle, (Army Experimental Station) Raubkammer bei Munster.
2. Heeres Nebelfüllstelle, (Army Charging Station) Munster Nord.
3. Erprobungsstelle der Luftwaffe (Air Force Experimental Station), Munster Nord.
4. Various establishments concerned with Nebeltruppen.
5. Munster Ost.
6. Luftwaffe Munitions Anstalt (Air Force Munitions Establishment), Oerel.
7. Heeres Munitions Anstalt (Army Munitions Establishment), Celle.

On reaching the target it was found that during recent months an evacuation of sections of the Army Ordnance Department dealing with chemical warfare development, (Wa Prüf 9) and of Heeres Gasschutzlaboratorien (Army Gas Defence Laboratory) Berlin-Spandau (Spandau) had been proceeding to Raubkammer. A quantity of equipment much of it as yet unpacked, from Spandau, and a number of documents from Spandau and Berlin were found. A considerable number of important members of Wa Prüf 9 and of Spandau were available for interrogation, and it quickly became evident that, especially in view of the situation in Berlin, the Munster Lager target had largely absorbed the Spandau and Berlin targets and had in fact become the key centre for obtaining information on the development of German Chemical Warfare. In addition, it became evident that Berlin, Spandau and Raubkammer were very closely inter-related and consequently in this report, they are treated as one entity.

This report is based upon an examination of the range, laboratories, plant and equipment, upon a preliminary examination of a mass of documents and samples, and upon a thorough questioning of all available witnesses. These with scarcely an exception were co-operative. The important witnesses interrogated are marked in Tables I, II and III with an asterisk, but in addition to these, a number of subordinate grades were also questioned. These are referred to where necessary in the body of the report.

The report is believed to give a fairly comprehensive picture of German chemical warfare research and development. The details given are, however, not complete, and as further witnesses become available, and when the documents and samples have been exhaustively examined, it should be possible to give supplementary details.

In particular, information is scanty on such subjects as the toxicities of new compounds, research on ointments and impregnates and production figures of C.W. agents and equipment. To fill these gaps requires the questioning of certain key personnel, who up to the conclusion of this investigation had not been traced. A list of these people is given in Table VII.

The thorough examination of the documents evacuated is not expected to give a great deal more information as the most important and recent ones had all been destroyed. Those discovered were, with the exception of three sets of microfilms which may contain data of value, mainly old or of secondary importance.

2. Organization of German Chemical Warfare Development

The organizations of Wa Prüf 9, Spandau and Raubkammer, are given in Tables I, II and III.

The following are some brief biographical details of the heads of Wa Prüf 9 and of Raubkammer :-

Oberst Dr Walter Hirsch.

Oberst Hirsch was born at Leoben in Steuermark on 8.2.97. He became an officer in the Austrian Army and in 1916 was a Lieutenant and Gas Defence officer. He served first in Russia and then in Italy where he became a prisoner of war.

In 1918 he went to the Technical High School, Graz, for three semesters and subsequently was again called to the Army.

From 1925 to 1929 he spent 8 semesters at the University of Graz studying Chemistry and Physics and received the degree of Dr. Phil. for work on perylene and indanthrene carried out with Prof. Zincke.

1934. He went to the Kriegstechnisch Amt, Vienna, and was put in charge of a small gas defence technical laboratory with the rank of major.

1938. Posted to the Waffenamt, Berlin, where he was first a Referant in Group VI and then Head of Group VI, Wa Prüf 9.

- Dec. 1940. Sent to Russian front in charge of a Decontamination Battery.
- 6.41. His battery equipped with 28 and 32 cm. Schwerwurf gerate.
- 1.42 Recalled to Berlin.
- 3.42 Appointed Head of Wa Prüf 9 in succession to Oberst Schmidt.

Major General Richter

Born 30.5.85. An artillery officer whose first contact with gas warfare appears to have been when he was posted in 1933 to Waffenamts S. In this year he was sent out to Tomka to disband the experimental station there. In 1934 he returned to Germany and was ordered to find and set up a suitable trial ground for gas warfare trials. He chose Raubkammer and was in command of the Truppenubungsplatz, Munster Lager, whilst all the buildings at Raubkammer were erected.

He appears to have had very little idea of the actual technical side of the work which was going on and was obviously merely in charge of the administration. He himself described his work as being "to see that every one worked the proper hours and that the necessary gates were closed for trials". He appeared to be more in touch with the work which was going on at the Nebeltruppenlager and was able to describe some of the training which was carried out there.

The head of Wa Prüf 9 occupied a very similar position in German chemical warfare to that of C.C.D.D. in U.K. and to that of the Assistant Chief, C.W.S. Technical Division. He controlled and directed all the research, development and test proceeding in all three establishments. To assist him in this, a committee consisting of members of his staff, were constituted as Gruppe I of Wa Prüf 9, but in fact this committee seldom met and control was virtually in the hands of Oberst Hirsch. He compiled a programme of work, but there was no formal machinery for obtaining the views of the user departments on this programme, and as far as can be gathered, these views were conveyed to Wa Prüf 9 in an ad hoc manner.

Wa Prüf 9 were concerned only with the development of the chemical side of munitions. The detailed design of the "ironmongery" of shell was the business of Wa Prüf 1 and of bombs of the Luftwaffe.

The head of Wa Prüf 9 delegated the direction of various aspects of work to the Groups and subdivisions given in Table I. The heads of these subdivisions known as "Referanten", have the detailed control

of the work proceeding in the Spandau laboratories and the Raubkammer ranges, each one dealing with the laboratory and field section corresponding with his own section of Wa Prüf 9. To a considerable extent the numbering corresponded, for instance, the referant of Group VIb controlled the work of VIbL Spandau and is largely concerned with RVI Raubkammer. The workers at Spandau and Raubkammer were allowed to know no more chemical warfare than was absolutely necessary to their work, although necessarily the referanten in Wa Prüf 9 had to have a somewhat broader picture. The general C.W. knowledge of all personnel questioned, except the very highest in rank, was found to be much less than to be found in corresponding ranks in the American or British service.

The numbers of employees at the three establishments were as follows :-

Wa Prüf 9	143 (peak 200 in 1944).
Spandau	450 (peak 450 in 1944).
Raubkammer	500 (peak 800).

The linkage between the three establishments may be illustrated by considering the method of investigating new compounds of possible Chemical Warfare interest :-

New ideas were obtained from five sources - (1) Their own research, (2) scientific literature, (3) Industry, via patents, or otherwise, (4) University work, (5) Intelligence. The new compound was first tried against animals in a 2 or 3 m³ chamber at a concentration of 500 mg/m³, either at Spandau or the Military Academy, Berlin. This test was found to eliminate about 99 per cent of compounds tried. Successful compounds were then examined at F3 Spandau in respect of physical and chemical properties, and again, if successful, by VIII Spandau for toxicological properties in 10, 50 and 100 m³ chambers. Lachrymators and irritants were tested against human observers and lethal gases against animals, the success criterion for the latter being a lethal Ct of 1000 mg.min./m³. The compound was next examined by the Spandau laboratories VIcL - explosion tests, VIbL - thermal generator, and VIaL for behaviour in various environments. This last was conducted in an ingenious and expensive apparatus in which temperature, humidity and air speed could be adjusted, rainfall imitated and into which a large number of representative soils could be introduced. By this time all compounds had been eliminated except perhaps two or three per thousand. Laboratories III and IIIL then considered the effectiveness of personal and collective protection towards the new gases, P2 and IIbL studied recognition and analysis and VIcL studied methods of dispersion, using the 250 and 1000 m³ chambers at

Spandau. Bursting trials in shell were next conducted by Gruppe VI in the Messhaus at Raubkammer, followed by field trials using the Vauzet tower or the Schienenkreis, (for details of these installations, see Appendix I). These tests usually eliminated all but approximately one compound out of every thousand originally considered. The final stage was the examination of the raw material position, the manufacturing process (VIII L and RVIII) and storage problems, which again usually eliminated more than half the survivors. It is interesting to note that it was not until this final stage had been reached that the Luftwaffe was informed of the position, so that they could give consideration to the use of the new compound in bombs.

Information was obtained on the functions of various other departments of the Army and other services in so far as they related to Chemical Warfare. This information is given in Table IV. In Table V ■ the chain of responsibility concerning chemical warfare in the Army is shown and Table VI is a diagrammatic representation of the relationships between Wa Prüf 9 and branches of other Service Ministries.

It will be noted that no mention of the S.S. occurs in any of these tables. Although the S.S. had its own Waffenamt (Ordnance department) with a chemical section, it was believed not to have its own chemical warfare organisation. The head of the S.S. Waffenamt was possibly General Gerloff. This organization worked entirely separately from the Army Ordnance department, and Prüf 9 were not allowed to give the S.S. any information, unless special permission had been obtained. The only possible link with the S.S. may have been through Wa.F. whose head, Prof. Schumann was well established in the Nazi organization. The activities of Wa.F. are referred to more fully in Appendix IX. It was also known that the factory at Falkenhagen for the manufacture of N-Stoff (chlorine trifluoride) was handed over to the direction of Übergruppenführer Schwab, a well-known S.S. chemist.

3. General Description of Raubkammer and neighbouring establishments

The Truppenübungsplatz (Training Area) is situated just North of Munster and consists of a fenced somewhat rectangular area of forest and heath about 16 km. x 8 km. This area was used as an experimental ground for Heeresversuchsstelle Raubkammer and Erprobungsstelle Luftwaffe and as a training ground for the 2nd Lehr (Training) Battalion of the Nebeltruppen (smoke troops), stationed at the Nebellager (smoke depot). Descriptions of the range and its equipment and of the various buildings mentioned below, will be found in the Appendices. A sketch map is attached as Fig. I.

The main administrative and laboratory buildings are situated in the South-west corner of the Truppenübungsplatz about one mile

from the town of Munster. This area (Fig.II) lies within an inner enclosure and contains an administrative block, an analytical section (RII), a section dealing with field trial apparatus and photography (RI); a decontamination and defensive appliance section (RIII); garages, workshops and gunsheds (RIV); medical section (RV); physiological laboratories with animal houses (RVII); hutted barracks and various ancillary buildings.

Just outside the gates of the main closed area is the Officier Heim, - a kind of officers mess - and the officers hotel, (used for accommodating official visitors) as well as the Commandant's house and a number of well built family quarters.

Along the road leading to Wriedel and each within its own enclosure are to be found the following sections (or separate establishments). First, a section (RVI) dealing with the preparation of experimental army gas munitions, which includes an office block and various weapon filling rooms and storage bunkers. Next is the Nebelfüllstelle, a large establishment for charging shell, nebelwerfe and chemical mines, and adjacent to this the Erprobungstelle der Luftwaffe, an independent establishment working in co-operation with Raubkammer for the preparation of experimental gas air munitions. The next section is RIX, for veterinary work, which is still incomplete, and finally RVIII which contains pilot plants for investigating the manufacture of new chemical warfare agents. In all these sections (except the Erprobungstelle der Luftwaffe) were found Spandau laboratory equipment in various stages of unpacking.

An account of the Nebeltruppen is given in Appendix VIII.

Brief descriptions of the Heeres Munitions Austelle (Army Munitions establishment) Celle, the shell dump at Munster Ost, and the Luftwaffe Munitions Anstalt (Air Force Munitions establishment) Oerrel, are given in Appendix IX.

4. History of German Chemical Warfare Development

The following summary of German Chemical Warfare research and development from 1924 onwards was obtained by interrogation.

- 1924. Min. Rat. Moyn and two co-workers, working under the Inspectorate für Waffen und Gerät started work on the preparation and study of known agents to obtain data on protection. A few extra-mural teams were involved.
- 1925. Work continued. Staff increased by two.
- 1926. Work continued. Analytical methods under study.

1927. Transfer of Group, without expansion, to the Waffenamt as Prüf S.
1928. Trials at Tomka, about 20 Km. west of Volsk., in Russia, commenced. Trials personnel approximately 30.
- 1929-1931. No change.
- 1932-3. Trials at Tomka ceased.
1934. Prüf S taken over by Major Dr Rudiger, as Wa Prüf 9, and expansion commenced. The emphasis was on gas protection; work commenced on detection and identification. Search for new agents in hand.
1935. Expansion continued. Field trials with improvised materials began at Munster. Building began at Munster and Spandau.
1936. CN and mustard adopted as the service C.W. agents, and development and testing of munitions for these agents predominated. Planning of factories, storage and filling plants for CN and mustard. Spandau and Munster essentially constructed. Search for new compounds continued; Tabun discovered.
1937. Strength of Prüf 9 now 80. Activities as before. Spandau and Munster working on development of experimental technique.
1938. Oberst Lieut. Dip. Eng. Schmidt head of Prüf 9, the strength of which was now 120, with expansion essentially concluded. Great efforts to finalise design of CN and mustard weapons to enable provision to commence. Intensive work on DA, DC; and DM. Trials at Munster to establish tactical principles. Experiments with Tabun at Spandau and Munster. Discovery of Sarin. Ammendorf commences manufacturing mustard and nitrogen mustard. Bitterfeld starts manufacturing phosgene. Seelze starts making CN.
1939. Similar to 1938. Experiments on arsenides. Investigation of material from Czechoslovakia and Poland. Dyhernfurth goes into production.
1940. Similar to 1939. Limitation of further work to such as might be expected to be concluded in 1941. Investigation of French material. Haselhorst goes into production.

1941. Intensification of work on viscous mustard. Air Force trials and charging of Air Force weapons received special attention. Excelsior studied at low priority. Gendorf goes into production.
1942. Oberst Dr. Hirsch head of Prüf 9. Changing over to new raw materials began to take up much effort, as materials became more and more difficult to obtain. The D-mustard process to be closed down. The difficulties of the Russian winter occasioned experiments at low temperatures in Norway. Work was limited, however, to questions of gas protection and smoke. For the requirements of the African theatre of war, smoke munitions were tested in North Africa. Experiments with substances such as HCN and CNCl gained importance in view of the possibility of their mass employment from the air. Special experiments at Spandau and Raubkammer as before; filling trials with Tabun and viscous H in the foreground. Trials with close combat munitions at Spandau and Raubkammer. Production stopped except at Gendorf and Dyhernfurth.
1943. An increase of personnel became necessary as the ever-increasing Allied air superiority heightened the probability of gas warfare against Germany. The heavy bombing attacks on Berlin provided the occasion of the removal of a part of Prüf 9 to Raubkammer. In all work the question of protection loomed even larger than before, since previously gas warfare was considered improbable, whereas now the danger that the Allies would start it was considered to be a real one. The provision of close combat weapons began to become more important. Experiments at Raubkammer to study tactics and to examine effects of weather. Series of field trials with Tabun.
1944. Specially intensive work on defensive problems. Struggle against raw material difficulties. Intensifying of experimental work on Tabun and the Sarin group. Trials on armoured combat with close range weapons.
1945. A small increase of personnel, chiefly on the defensive side. At the beginning of March, removal of Prüf 9 as well as the major part of the Spandau personnel to Raubkammer. Work as in 1944. Sarin scheduled for production at Dyhernfurth at the rate of 100 tons per month commencing midyear. Sarin plant at Falkenhagen with capacity 500 tons/month about 25 per cent complete.

5. Summary and appreciation of German Chemical Warfare Development

(A) Defensive aspects

The German measures for the defence against gas were highly organized and characterised by the multiplicity and elaborate nature of the devices developed for individual and collective protection, for detection and for decontamination. Much was already known to us from captured material and documents, particularly since the D-day landings, but the investigation at Raubkammer served to clear many points that were obscure and a great deal of detailed information was gained on the German methods and the trend of their developments. Details are given in Appendix II; comments of general interest are dealt with below.

- (i) Respirators. The German design of respirator container was greatly influenced by their fear of the use against them of hydrogen cyanide and cyanogen chloride in high concentrations. To meet the danger from hydrogen cyanide they introduced the Fe42 container and later they impregnated the charcoal with crude higher homologues of pyridine in order to obtain better protection against cyanogen chloride. Some 8 million Fe42 containers were manufactured, but the opinion was expressed that their introduction was a mistake; the facepiece was unbalanced and the protection was unnecessarily high. Adoption by the Germans of multiple layers of charcoal in their container was enforced upon them by supply considerations. The steam activated (Wsa) charcoal which they would have preferred to fill alone into their container was in demand for other purposes and only a third of the quantity needed for respirator production could be provided. Accordingly, layers of other charcoal of high absorption capacity but relatively low retentivity were introduced. Mixing of the various kinds of charcoal was not put into practice owing to packing difficulties due to variation in grain size and shape of the different kinds of charcoal. Various types of clip on extension containers were tried for improving the protection of existing containers or for prolonging the life of partially exhausted containers. Although some of these made from cardboard were successful they were not accepted as a service store. There had been no recent advances in the design of particulate filters. The ring type paper filter had been found to be very effective and work was being devoted merely to simplifying details of manufacture.

Waterproofing of the filter had been introduced some time ago and this was indicated by the Δ mark on the container.

Recent developments in facepiece design included a new type, the Gm43, with improved speech characteristics and an entirely new model, the Gm100, which was being tried out owing to the acute shortage of rubber and other essential materials. The Germans were impressed by the excellent speech valves in the British and U.S. respirators, and in the Gm43 they had introduced a form of membrane expiratory valve which, although not as effective as the British and U.S. devices, gave them 50% improvement over the valve in the Gm38. Owing to our bombing, the production of these facepieces was inconsiderable.

The Gm100 was made from canvas backed with a thin layer of rubber. The head harness was mainly of rubber and valves and eyepieces were of simplified design. This facepiece had not been made in quantity, but an even more simplified version, known as the Vm44, was being produced for the civilian population.

The Germans were concerned about facepiece leakage. Trials in high concentrations of gas from the burst of bombs disclosed that there was leakage through the expiratory valve. Although this was not physiologically significant, it might be psychologically disturbing to the troops. Various expedients such as attaching a small charcoal container outside the valve proved successful, but the device was not actually manufactured. The fear of hydrogen cyanide led to the development of the mouthpiece and nose-clip device for quickly obtaining protection. About 500,000 were ordered but they were not in general issue.

It is evident that the Germans endeavoured to obtain protection not only against the gas concentrations which they knew could be attained with existing weapons but also against much higher concentrations which they believed might be achieved in the future by improvements in weapon design. Much of their defensive effort had to be diverted, especially during the last year, to the search for substitute materials for components for their respirators.

(ii) Collective Protection. Installations for the gas protection of civilian and military shelters had been constructed on a large scale. Filtration units were made in standard sizes for dealing with flow rates of 0.6, 1.2, 2.4 and 10 m³/min. respectively. Although

of conventional design, they embodied many features of interest which will be dealt with in the Appendix and in the report on Draeger-Werk. Testing was very thorough, particularly as regards flow rates, and, as production was restricted to two firms, there was no difficulty in obtaining uniformity in construction and performance.

Lately, an attempt had been made to obtain production by improvised means. Sand on a bed of coke was used as the filter medium and was found to be effective against mustard vapour. A sufficiently high ventilation rate could be obtained from manually operated bellows made up from scrap wood and a gas plane or similar material. It was considered that the danger from non-persistent gases could be dealt with by closing down ventilation completely over the period of the attack.

Gas protection of tanks had received considerable attention. The latest idea was to instal a complete filtration unit, including fan, dust, smoke and gas filters, inside the tank in order to maintain a slight positive pressure thus obviating the need for providing each member of the crew with his individual fresh air supply. Development was in the trial production stage, but the units soon suffered from the serious drawback of being excessively large.

- (iii) Detection. The Gasanzeiger had reached a high pitch of development and, apart from the possible introduction of new testing tubes, no modifications in the general design of the kits as issued to the forces were contemplated. There were indications, however, of a change of view on the whole question of gas detection in the field. Those with experience thought the Gasanzeiger to be too slow and difficult to use. Experiments were being made with silica gel absorbent discs which, after sampling, could be subjected to spot tests. Much attention was also being paid to detector papers. New papers had been developed for detecting hydrogen cyanide (also used for Tabun although non-specific), Tabun, Sarin and Soman (specific for phosphoric esters), Cyanogen chloride, nitrogen mustard, and carbon monoxide. A night detector paper for ground contaminants had also been developed. The Germans were greatly concerned with the detection of carbon monoxide, but apparently nothing fundamentally new in principle had been discovered. A semi-automatic detector for

use in tanks and enclosed spaces is, however, one development of interest.

The Germans were not satisfied with their detector paint and when the British paint was captured, it was copied and introduced into service.

- (iv) Protective Clothing. Although the Germans had done a great deal of work on impregnated clothing, the investigation had never passed beyond the experimental stage and a general issue was not contemplated because of the shortage of raw materials for making the impregnants. They were hoping to introduce a form of battle-dress in 1945 when the question of impregnation was again to be considered. Their interest in the subject was first aroused by the capture of documents after the fall of France. British and American type impregnating agents were tried. Jackets, trousers, underclothes and socks were treated, but the impregnation of the latter two was not at all successful because of the stiffness and general unwearability of the finished product. A laundry impregnation method from a benzene dispersion and a field method from an aqueous dispersion using commercial emulsifiers were developed. Soldiers were averse to wearing the impregnated clothing because of its stiffness and smell, and under certain circumstances it caused dermatitis and cyanosis. In wear, it lasted about four weeks, and in storage, about six to nine months. It would appear that the German impregnated clothing was inferior to the British and American products and, in point of fact, it was not of much value.
- Many types of impervious clothing, both for men and animals, were found. The Germans were greatly concerned with the discomfort and distress due to heat and moisture when the clothing was worn for any length of time and made many attempts to overcome this difficulty. A number of ingenious methods of ventilating completely enclosed suits were tried but none appear to have been successful.
- Owing to shortage of apparel and nylon, the original casein-ammonia coated paper had recently come back into production for gas planes.

- (v) Decontamination. The methods for decontaminating uniforms, gas masks, leather, and rubber protective clothing followed on the usual lines and details are given in the Appendix. On the experimental side, no new or startling developments were apparent. Mechanical

methods for ground decontamination were well developed. Particular use was made of ploughs in the field.

(B) Offensive aspects

The general policy of Wa Prüf 9 which guided the development of agents and munitions may be summed up as follows :-

1. Gas munitions come into three categories - harassing, defensive and offensive. It was considered wasteful to use a munition developed for one purpose for any other. This principle guided all work and its effect can be traced throughout munition design.
2. Harassing weapons were those containing CN and DC, or DM or newer arsenicals.
3. Defensive weapons were those which distribute vesicants, usually thickened, on the ground to prevent enemy traversal, or occupation/fear of liquid contamination.
for
4. Offence could be achieved by the following means :-
 - (a) The lavish use of agents of moderate offensive power such as phosgene, and initial-cloud mustard.
 - (b) The use of a gas which is so lethal that it is effective before the respirator can be adjusted.
 - (c) The use of an undetectable gas.

The last two principles guided the research which resulted in the discovery of Tabun, Sarin and Soman (see below).

The German appreciation of the tactical use of the orthodox gases was not highly developed. Their field trials were designed primarily to aid the development of individual weapons, and not to determine the way in which they should be used, or the quantities required for effective action. Their field trials tended to be stereotyped and unimaginative and consequently the inferences drawn from them were not always of a realistic nature. An account of German gas tactics is given in Appendix X.

No real effort had been made to extrapolate the toxicities of the common C.W. agents from animals to man and their dosage criteria for offensive purposes are lower than accepted in America and United Kingdom.

Details of the German munitions are given in Appendix IV, and of the properties and physiological effects of the chargings, in Appendix III. It is proposed in the following paragraphs to summarise this information.

Orthodox War Gases

Mustard gas (and its admixtures) and phosgene were the two orthodox war gases into which the Germans had put their greatest manufacturing effort, the latter being the principal filling for aircraft bombs. Additional orthodox war gases, which it was proposed to use to a smaller extent, were HN-3, CN, DM and AC.

- (i) Mustard Gas. Two distinct uses for mustard gas were envisaged; first for non-persistent assault effect and secondly for persistent ground contamination effect. To obtain the first of these, shell and bombs with very large bursters had been developed and a great deal of effort had been put into research and experiment in H.E./Chem. shell and bombs. For some time this was the main development effort with mustard but later on attention was turned to obtaining ground contamination by means of thickened mustard from ground burst shell and ground burst and airburst bombs. A good deal of attention was also given to static methods of ground contamination. The use of ground contamination for giving offensive effects by the vapour evolved over a period was not fully appreciated, and ground contamination was regarded as mainly effective in a defensive manner by creating a traversal hazard. No real attempt was made to determine the casualty producing dosage for H vapour on human skin. The H.E./Chem. munitions were charged with straight undiluted mustard (Sommerlost) for use in warm weather, and for use in cold weather, with various mixtures of mustard gas with, for example, anthracene oil, arsinol (a mixture of DA, phenyldichlorarsine and triphenyl arsine) and with isomeric dimethyl derivatives of mustard, known as "Winterlost". Winterlost was used in shell only; production was insufficient for charging into bombs. The minimum density of mustard gas considered to give a useful ground contamination effect was 100 gm./m² but the extent of the hazard was never determined by trial. The thickener used for thickened mustard (Zählost) was chlorinated rubber (tornesit). A search was in progress for an alternative thickener and polystyrol had been chosen, polymethylmethacrylate having been rejected on account of non-solubility. Work had

started on the use of radio, barometric and other types of fuze calculated to give air-burst, but little progress had been made.

The use of mustard sprayed from a low level was advocated by Wa Prüf 9 but not accepted by the Luftwaffe. The weight of spray falling on a man was considered the criterion of offensiveness, and no regard was paid to drop size, although it was known that larger drops were better than small ones. The contamination necessary to cause a clothed man to become a casualty was given as 5 gm/m^2 , but this was an inference based on animal trials. No work had been done on high spray, although it was scheduled to commence at a range in Galicia in 1944.

Work had commenced on the production of mustard gas vapour from thermal generators, but no success had been achieved.

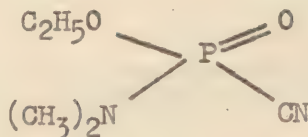
- (ii) Phosgene. This gas was used in bombs only, the 250 kilo bomb being the standard one, with a 500 kilo bomb coming into use and the 1000 and 1800 kilo bombs still under development. Phosgene was the principal charging for bombs. The idea of charging shell with phosgene was abandoned in 1934. Phosgene was the only lung irritant in use. Stocks of chloropicrin were held but were for use as a fumigative agent.
- (iii) Nitrogen mustard. This was charged into both shell and bombs of the high burster type to give initial cloud attack. It was considered to be 20 - 30 per cent superior to mustard for this purpose, but was not available in very large quantities.
- (iv) Chloroacetophenone. This was used in shell and bombs to give harassing effects. It was the only lachrymator in general use.
- (v) DM. This was used in static generators, shell and bombs as a harassing agent. It was believed that by using static generators which closely resembled the French Engin Z it would be possible to enforce the wearing of the respirator continuously over a wide front to a depth of many kilometres for a period of days. No idea of penetrating the respirator was entertained. In examining the effects of this gas, description of symptoms by observers was relied on, and no performance tests were imposed. Blue ring 1 and Blue ring 2 shell were of the bursting type, but Blue ring 3 shell, a base ejection type, was considered greatly superior in performance to the other two, although manufacturing

difficulties hindered its adoption. The use of DM and arsenicals generally was restricted by a shortage of arsenic.

- (vi) Hydrogen cyanide. Many spraying trials had been carried out with AC charged into Russian VAP.500 spray tanks, and into the S.500, a German copy of this weapon. They came to the conclusion that lethal concentrations of AC could be put up in this way especially in tanks and fortifications. This conclusion was based upon what is considered to be the erroneously low lethal dosage for AC of $Ct = 1000$. They would have been unable to use this weapon as insufficient hydrogen cyanide was available.
- Hand grenades and glass bulbs charged AC had been developed but were not in production. Both were considered to be excellent weapons against tanks and fortifications. The German had had similar experiences to our own on the question of stability and inflammability of HCN.
- (vii) Cyanogen chloride. was not considered to be a good war gas since surprise lethal effect could not be obtained. A plant for its production was however under construction. They had apparently not considered the possibility of obtaining sufficiently high concentrations to defeat the respirator, except possibly by hand-spraying into fortifications, although they were well aware of the desorption phenomenon.

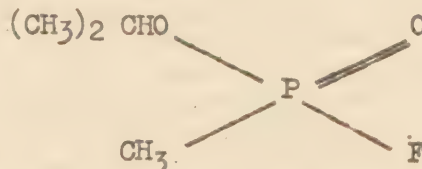
New Gases

- (i) Tabun, Sarin and Soman. A new gas, Tabun, (British T.2104) with the formula

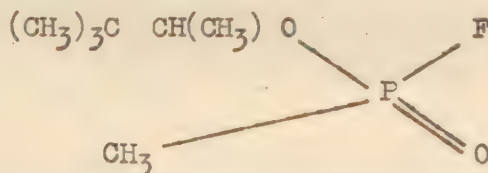


had been developed and was in production at Dyhernfurth at a scheduled rate of 1000 tons/month. This gas, which is a nerve poison causing contraction of the pupils at a very low dosage and reputed to be lethal at a dosage of $Ct = 300 - 400$ was considered to be exclusively useful as a non-persistent gas, and was intended for use only in shell. Bombs were charged with it, but only for storage purposes (although it seems likely that, in

fact, these bombs would have been used had C.W. broken out). A search for related compounds had been made, and as a result two important substances were revealed, Sarin and Soman. Sarin has the formula



Its lethal dosage was given as Ct = 100-150, and its volatility is higher than that of Tabun. Moreover, it was stated to be odourless. Its preparation on a large scale was difficult, but a method for doing this had been evolved and a pilot plant had been in operation at Raubkammer, scheduled for an output of 5 tons/week. So far, only $\frac{1}{2}$ ton had been made, and clearly all problems in connection with the manufacture had not been overcome. It was intended that Sarin should replace Tabun and plants for its manufacture at the rate of 600 tons/month were being equipped. Soman, which appears from the information available to be still more toxic than Sarin (lethal dose possibly less than 100), is



Its manufacture was still in the laboratory experimental stage.

The Germans were cautious about claiming too much for Tabun, which they recognised as having only a lung effect (no great stress was laid on the eye effects) against which the respirator was a protection unless surprise is effected. They pointed out that decomposition was extensive on detonation and they also considered that its smell was too pronounced and its volatility too low restricting its use to warm weather conditions. Moreover, manufacture was difficult and limited by a shortage of phosphorus. They had, however, greater hopes for Sarin on account of its effectiveness in low concentrations and the greater chance of causing a surprise

effect conferred by the absence of smell, but the difficulty of manufacture and the shortage of phosphorus still remained as disadvantages.

- (ii) Aeroform. This is a mixed aluminium and magnesium arsenide (Al 91 per cent, Mg 9 per cent) which was developed as the outcome of experiments to obtain toxic effects from incendiary bombs. The first idea was to include arsenious oxide as a constituent of a thermit composition, so that metallic arsenide would be produced on combustion and the residue evolve arsine on contact with water, thus hindering fire fighting. This developed into the inclusion of a component containing a quantity of previously prepared metallic arsenide, and an incendiary bomb on this principle, the Bi iv/99 was manufactured in small quantities. It was never put into service however, as it was realised its use would be considered initiation of gas warfare. Aeroform was the final metallic arsenide developed; this was made on a small research scale at Bitterfeld. Plans to make on a 300 tons/month scale at Dyhernfurth were considered and building started, but later given up. Aeroform generates arsine extremely quickly in moist air, the gas being practically odourless. After the abandonment of the incendiary bomb idea, experiments on the use of Aeroform in large bombs showed that in woods what was considered to be a lethal dosage ($Ct = 1000-2000$) could be obtained from a distribution of $50-100 \text{ g/m}^2$. Research on grain size showed that there was no advantage in grading, the product as supplied giving sufficiently good results. Several thousand kilograms of Aeroform were captured and are being returned to U.K. for distribution. The effectiveness in tropical forest, a subject in which the Germans were not interested, might be well worth while determining.
- (iii) Phosgene oxime. The Germans had heard that the Russians intended to use Phosgene oxime. They put a considerable amount of work into studying this gas and its mixture with mustard, and formed the opinion that it would constitute a potent C.W. material, largely owing to the intense pain caused by contact with the skin. Technical details of a manufacturing method were being worked out at Haselhorst.
- (iv) Excelsior. This compound, 5-chloro-5:10 dihydroarsacrine was considered to be superior to DM as an irritant

and had been taken to the stage of pilot plant production. It had the disadvantage of being difficult to handle, because of ease of decomposition in the presence of air and moisture, and no decision had been made to adopt it.

(C) Smoke

The German Army had no very great interest in smoke, although both the Luftwaffe, for anti-aircraft screening, and the Navy used it in large quantities. Latterly, the Army had begun to take more interest, after noting the uses to which smoke was put by the Allied Forces. There were a number of generators of the smoke mixture type available which, although efficient, present no outstanding point of interest. The apparatus for using chlorosulphonic acid mixture was of excellent construction, this material being used almost exclusively for anti-aircraft screening. They were, however, beginning to consider the use of black smoke generators of a conventional type for use at night. They did not use oil smoke and were mystified by the oil smoke generators used by the Allied Armies. Smoke shell, rockets and mortar bombs contained sulphur trioxide, the reason being that this was available whereas phosphorus was not. They were developing base ejection shell which were considered preferable to ground burst sulphur trioxide shell, but had not achieved production on a large scale.

(D) Experimental Manufacture

Units capable of investigating the manufacture of new war gases up to a capacity of about 10 tons material per week were available at Raubkammer. Plants for Excelsior and for Sarin were in existence. The former had produced about 10 tons of good product, but the latter had so far produced no more than 0.5 ton. The plants embody several novel features, which are described in Appendix V. Some of the stages necessary for the production of Sarin introduce difficult design problems and it does not appear that these had by any means been fully solved, although a large output of Sarin at Dyhernfurth was scheduled to begin in the summer of 1945. Most of the experimental work on mustard production was carried out at I.G. factories. Production methods for DA, Arsinol, lewisite and phosgene oxime appears to have been studied at the Lonal Works, Haselhorst.

(E) Charging methods

The machines used for charging of weapons were of two types, automatic and semi-automatic. Fuller details of these

machines which were designed by Hagenuk, than are given in Appendix IV will be obtainable at another target, but the impression formed was that the automatic machines are highly complicated and require very skilled maintenance, whereas the semi-automatic machines err on the side of clumsiness. The layout of the Nebelfüllstelle which is one of the five charging plants existing in Germany was very well done apart from the charging machines themselves, and the general disposition is considered most convenient and efficient.

(F) General

The total effort put by the Germans into chemical warfare research and development was considerable, the scientific staffs employed as far as can be ascertained, being about double the numbers employed in Great Britain. The buildings and equipment provided were on a lavish scale, and it was clear that not only was no expense grudged in providing laboratory space and apparatus ample for the immediate programme, but that reserve stocks and space were available for accommodating a large expansion of research staff.

The outstanding achievement of German chemical warfare research has undoubtedly been the discovery of Tabun, Sarin and Soman. Apart from this, however, there was a surprising lack of originality in their work, and important phases of C.W., such as micrometeorology, the vapour effect from mustard ground contamination and ointments were given small or belated attention. When once the significance of a discovery or development was seen, however, it was usually followed with great thoroughness. Particularly was this so when an intelligence report of any new development in an enemy country was obtained, and it is a remarkable fact that a great deal of the total research effort went into the pursuing of such ideas with the greatest tenacity. Another great part of the German research effort was, in the last two years, put into the discovery of substitutes for various raw materials and intermediates which were, owing to Allied bombing, becoming difficult to obtain.

6. Japanese chemical warfare

It was not possible to obtain any information on Japanese chemical warfare since little exchange of information took place between the Germans and the Japanese. The former in 1944 supplied 10 GM38 facepieces, 50 Fe41 containers and 10 or 20 carbon monoxide filters (type unknown) for examination by the Japanese; in return they were to have received Japanese facepieces and containers but these never materialised. A Japanese naval officer in 1943 visited

Spandau to obtain information on carbon monoxide filters, and he may possibly have later visited the firm of Auer.

A monthly liaison meeting was held at which Oberst Hirsch and Min. Rat. Dwillling met Col. Otiai, a Japanese Technical attaché. These meetings were for the purpose of exchanging foreign C.W. intelligence, but in fact the meetings never lasted more than half an hour and consisted of nothing more than a brief general conversation. No information of any interest was given. Oberst Hirsch had instructions not to divulge any information concerning German C.W. preparations or development. He could give no information on any aspect of Japanese Chemical Warfare.

TABLE I

Wa. Prüf. 9

Head	-	Oberst Hirsch *	Adjutant	-	Major Heitefuss
Group I		Organisation and Direction			Oberst von Dechend Sodemann
Ia		Technical matter			Min. R. Prof. Marks *
Ib		Chemical matters			ORBR Prof. Wagner *
Ic		Service matters			
Id		Correspondence with In. 9.			
Group II		Gas Defence			Min. Rat Dr. Schmidt *
IIa		Gas masks etc.			Oberstlieut Wobit
IIb1		Respirator fillings			RBR Dr. Mieller *
IIb2		Gas planes etc.			RBR DR. Strauss. Ing. Schmid.
Group III.		Decontamination and Gas Detection			Prof. Fritz Wirth
IIIa		Collective protection			OB Ing Franke
IIIb		Detection			RBR Dr. Guggolz *
IIIc		Decontamination of ground and foodstuffs			ORBR Dr. v. Mullenheim Franzke
Group IV.		Mechanical			Min. R. Prof. Marks *
IVa		Ground Decontamination			" } - Ing
IVb		Troop Decontamination			" } Canzler *
IVc		Filling Plant			RBR Dr. Müller
Group V		Extra Mural Research			ORBR Prof. Wagner *
Va		General Chemistry			Dr. Reimer
Vb		Card Index etc.			Dr. Roch
Vc		Censorship			Dr. Rauchhaupt *
Vd		Literature			Dr. Roch
Group VI		Gas and Smoke Weapons			Min. Rat. Weinberg * -
Vla		Ground Contamination			Adjut Mengele *
Vlb		Smoke and Gas Clouds			ORBR Dr. Nobbe * -
Vlb(1)		{ Gas clouds }			Oblt Dr. Gabel
Vlb(2)					Dr. Kappes *
Vlb(3)		Smoke equipment			Dr. Kappes * - Ob. Amt.
Vlb(4)					Gritzka *
Vlc		Grenades, igniters, etc.			Ob. Ing. Thiel
Vld		Infantry and Small Arms.			Dr. Flugel, Alfred *
Vle		Artillery			Dr. Bull *
Vlf		Meteorology			RBR Dr. Schreiner.
		Air Weapons			Dr. Schmeiss
					RBR Dr. Kaiser
					ORBR Dr. Nobbe *

Group VII		Oberstabartz Prof.
		Dr. Wolfgang Wirth
VIIa	Testing of new substances	Oberstabartz Dr. Kruse *
VIIb	Field Trials	Oberstabartz Dr. Prüsener *
VIIc	Hygiene and Bacteriology	Prof. Kliewe. Oberstabartz.
Group VIII	C.W. Manufacture	Ministerialrat Dr. v. d. Linde *
VIII(a)	Technology	Ministerialrat Dr. v. d. Linde *
VIII(b)	Chemistry of Manufacture	Reg B. Dr. Gebhardt
VIII(c)	Factories	
Group IX	Finance etc.	Obltn Klingbeil
Group X		Min. Rat. Dr. Stantien
X(a)	Incendiaries	Sdf Dr. Herold
X(b)	Attack of Tanks	Haupt Bohm
Group XI	Patents	ORBR Dr. Janssen *
		Dr. Winkler * gone to V.W.L.
Group XII	Intelligence	Min. Rat. Dr. Dwilling *
		Major Clement
Group XIII	Veterinary	Oberstabartz Dr. Reinecke
		Stabsvet Dr. Meyer
		" Dr. Rygsicke
		" Dr. Turrel
		Dr. Niemann
Z.B.V.	Special duties as occasion arose.	Oberst. Von. Sicherer

* Interviewed during compilation of this report.

TABLE IIHeeres Gasschutz Laboratorium SpandauLeiter - Oberst Dielitz ⁺

F1	Chemical Synthesis	O.B. Dr. Reetz * O.B. Dr. Bottger
F2	Analytical Chemical	Dr. Kolliker, Rudolf ⁺ Dr. Wolf Dr. Schlinker
Lab. 1.	Polarimetry	Dr. Ender Dr. Vogt, Heinz
Lab. 2.	Sarin and Tabun Work	Dr. Wolf, Johannes
Lab. 3.	Booty examination HCN determinations Ampoules for Storage trials.	Dr. Schlüter, Rudolf
Lab. 4.	Mustard derivatives	Dr. Kobs, Hans *
Lab. 5.	Chamber trials	Dr. Ulm, Rudolf *
Lab. 6.	Sarin research	Dr. Kolliker
F3	Microchemical and Physicochemical Phys. Measurements - Smoke Adsorption and Desorption of charcoal. Mol. weight Measure- ments.	Prof. Jung B. Schweckendick * Dr. Wolf * Dr. Holm Dr. Siemens, Dr. Kasel *
F4	Measurements or Con- centrations on Filas etc.	O.B.R. Dr. Zeumer Dr. Leopold Dr. Sperling
F5	Library	Dr. Metzener Dr. Grassow *

III	Personal Protection	O.B. Dr. Kock Dr. Bottman Dr. Mai Dr. Schönmann *
IIIL	Collective Protection	O.B. Dr. Schultz - Overberg
IIIaL	Filter units	Dr. Abel
IIIbL	Detection and Recog.	Dr. Schaeffler Dr. R. Schönmann, Rudolf *
IIIcL	Decontamination	Dr. Meiner * - Gunzel *
IVL	Mechanical	O.B. Dr. Holtzapfel
VWL	Physiological Chemical	Dr. Winkler *
VIaL	Ground contamination	O.B. Dr. Stuhldreer, * Dr. Heinz Feigs *
Lab. 1.	Dust	Dr. Feigs * Hahnel * Bolke
Lab. 2.	Organic chemicals	Dr. Füsting
Lab. 3.	Organic chemicals	Dr. Füsting
Lab. 4.	Mustard	Dr. Stuhldreer
bL	Smoke and thermal generators	O.B. Dr. Marin, O.B. Dr. Hildebrand * Dr. Carls * Dr. Mehls, Karl * Dr. Tanne, * Dr. Herrmann
cL	Small scale development of shells - HE tests for shells.	Dr. Strasser, Otmar * Dr. Fensch, Walther *
dL	Meteor	Dr. Boschmann (?)

VIII	Toxicology	Oberstartz Dr. Sextel H.A. Dr. Böttger, Gerhard *
VIII	Semi-Technical Scale Plant.	Dr. Dörken Dr. Niggemeier Dr. Stadler * Dr. Schusteritz *

* Oberst Dielitz and Dr. Kolliker were stated to have been killed during the fighting in Berlin.

* Interviewed during the compilation of this report.

TABLE III

Heeres Versuchsstelle Raubkammer Bei Munster

Leiter - General - Maj Richter[■]

Hauptburd A1	Administration	Major Bauer [■]
Bereich A1b		
Bereich A2	Finance	Oberzahlm Löwenstädt
Bereich A3	Q.M. Stores	Oberschirmm Ropers
Bereich A4		O.R.B.R. Dietz [■]
Bereich B	Ordinance Stores	Obberinspektor Hahn
Bereich RI	Field Trials	Major Pistor [■] Ungeft Zachow [■] (Photography)
Bereich RII	Chemical Analysis	O.R.B.R. Weinzierl [■]
Bereich RIII	Decontamination and Detection	R.B. Dr. Kuhk [■]
Bereich RIV	Vehicles and Work-shops. Modifications and prototype construction.	O.R.B.R. Dietz [■]
Bereich RV	Medical (Field Trials) and Toxicology	Stabsartz Dr. Budde
Bereich RVI	Experimental Filling and Charging Plant	Chemiker Dr. Vogel [■]
	Administration	Insp. Striebel [■]
Bereich RVII	Medical (Treatment of Casualties)	Oberstabsartz Prüsener [■]
Bereich RVIII	C.W. gas Pilot Plant	R.B.R. Dr. Erwin Fahrenholts
	Supervisor C.I. house on sarin manufacture	Dr. Jannsen, Rudolf [■]

Shift foremen	(Dr. Schusteritz *
	(Dr. Killinger *
	(Dr. Richter *
C. Houses	Dr. Artelt, Heinz *
Ex. Plant	Ing. Schneidewind
Bereich RIX Veterinary	Prof. Doctor Borchers *
	(till Jan. 1945)
	Stabsveterinar Meyer
	Stabsveterinar Knebel

Erprobungstelle der Luftwaffe

Air Force weapons	FL. Stabs. Mg. Dr. Pritzkow.
	FL. Stabsing. Dr. Multone.
Smoke and chemical aspects of S.C.I. use.	FL. Stabsing Grüner.
Maintenance of S.C.I. and i/c workshops.	FL. Stabsing Zuschrott
	FL. Haupting. Dr. Frank.
	FL. Haupting. Dr. Marthaler.
	FL. Ing. Beckert.

Heeres Nebelfüllstelle, Munster Nord

O.C. Depot	Hpt. Baumann, Karl.
Munitions Officer	Lt. Bauer.
" "	Lt. Ritter. *
Technical Foreman	Trautmann, Georg *
Filling Plants.	

* Interviewed during compilation of this report.

TABLE IV

A R M Y.

Usual name or abbreviation.	Full name.	Chief personalities.	Functions.
<u>Generalstabd.</u> <u>Heeres:</u>	General der Nebeltruppe	Generalleutnant Ochsnr. Oberstleutnant Heimann. Oberleutnant Kassebarth.	Training and equipment of troops in the field. Liaison between General Staff - AHA - "aa. General questions of gas defence, at first for Army only. Since 1st April, 1945 for OKW. Publication of Intelligence Summary concerning Gas warfare preparations in foreign lands. Chief advisor in OKW.
General der Panzertruppe Inspekteur der Panzer- truppe.		General der Panzertruppe Guderian Oberstleutnant Dr. Korbler	General gas protection for Panzer motorized units. Defensive and Offensive munitions for A.F.V's.
Gen. d. P. u. F.	General der Pioniere und Festungen	General der Pioniere Jacob einige Fachbear- beiter.	Gas defence for forts. Assault equipment against forts.
	General beim Chef H-Ruest und B.d.M.	General der Infanterie Buhle.	Adviser to commander of the Ersatzheeres (Re- placement Army) on technical military matters.

Usual name or abbreviation.	Full name.	Chief personalities.	Functions.
AHA: In 4/Ag Art.	Allgemeines Heeresamt. Inspektion 4 Amtsgrupps Artillerie.	----- ?	Firing directives for artillery. Practical questions regarding tactical use of war gas.
-do- 1. H.N.	Leitender Heeresmeteorologe	Prof. Min. Rat. Kolzer Baurat Dr. Lucke.	Meteorological Service for Army Examination of Porton Reports.
In. 5.	Inspektion 5	?	Close-combat material and smoke.
In. Fest.	Inspektion Festungen	?	Gas defence of forts. Munitions for attacking forts.
In. 6.	Inspektion 6	Major Fechner.	Gas defence for Panzers, Flares.
In. 9.	Inspektion 9	Oberst Engelter. Major Prohaska. Major Dederscheck. Atsrat Beck. Inspektor Heise. Min. Rat. Dr. Fischer.	Directives and personnel of smoke troops. Replacement and training of smoke troops. Tactics of gas defence and offence. Directives for development, and testing of experimental materials by troops. Introduction of stores. Supply questions. Troop exercises.

SIn.	Sanitaets- inspektion.	Oberstarzt Prof. Dr. Wolfgang Wirth Prof. Dr. Kliewe.	Medical gas defence problems. Training of doctors and sanitary personnel with service groups, armies etc. Troop decontamination formations, and their equipment. Gas Therapeutics. Toxicology and Therapy. Skin decontaminants. Training of military doctors.
	Militaer- aerztliche.	Oberstarzt Prof. Dr. Wolfgang Wirth Oberstapotheker Dr. Gemeinhardt.	
	Truppenent- giftungs- Lehrkompanie.	?	Training of troop decontaminating companies and trials with their equipment.
VIn.	Veterinaer- Inspektion. Veterinaer- Akademie.	Gen. Vet. Dr. Schulz. Oberst-Vet. Geweniger. Gen. Stabs-Vet. Prof. Dr. Richters.	Training of veterinary troops. Directives concerning animal gas defence. Special training for Veterinary surgeons. Toxicology and Therapy in relation to veterinary matters.
FzIn.	Feldzeug- Inspektion.	Oberstleutnant Matt.	Supply and storage at charging stations and munition dumps. Filling and transport of gas shell. Storage of captured munitions. Supply via quartermaster general of Home Forces of chemical munitions.

Usual name or abbreviation.	Full name.	Chief personalities.	Functions.
Waa.	Heereswaffenamt.	Gen. d. Art. Leeb.	
Waa Chef. Ing.	Chefingenieur.	Min. Dir. Dill. Ing. Pollert. Baurat Dr. Siegfried Schmidt.	Academic personnel of Waffenamt. (Ordnance Department)
Waa Chef. Ing. I.		Min. Rat. Dr. Leinweber	Examination of specifications, inventions and patents.
HTB.	Heerestechnisches Buero.	----	Preparation of drawings and assembly specifications.
F. U. Kdo.	Kommando fuer Fertigungs- und Terlagen.	?	Supervision and supply of specifications to inspection department and contractors.
Wa Chef. Chem.	Chefchemiker des Waffen- amtes.	Oberst Dipl. Ing. Letis (O)	General questions of chemical and raw material supply for Ordnance department.
Wa Z 4.	Zentralabteilung 4.	Oberstleutnant von Harsdorf. Oberstleutnant Goellner Min. Rat. Dr. Oelshausen (Obelshausen).	Equipment directives and nomenclature.
Wa/Ro.	Rohstoffabteilung.	?	General raw material and contingent questions.

Wa/Abn.	Abnahmeabteilung des Waffenamtes.	Oberst Justrow. Oberstleutnant Dipl. Ing. Nowotny (ö)	Acceptance of gas defence and smoke equipment. Acceptance of war gas munitions, smoke stores and igniters etc.
Abn. 1.		?	
Abn. 2.			
Abn. 3.			
Wa.F.	Forschungs- abteilung.	Min. Dir. Prof. Dr. Schumann. Oberst Dipl. Ing. Plas. Min. Rat Prof. Dr. Eschenbach. Ober-Reg. Baurat Dr. Glupe. Reg. Rat Dr. Schoenwaldt Reg. Rat Dr. Drinks.	N-stoff and physical questions. N-stoff and Seewerke. Ultra-violet research. Hollow charge effect. Rocket research. Ray research. Radio-activity research, etc.
Wa/Pruf.	Amtsgruppe Prufwesen	Gen. Leutnant Dipl. Ing. John.	Infantry weapons.
Wa/Pruf. 2.	Infanterie- abteilung.	Oberst Dipl. Ing. Kittel	
Wa/Pruf. 4.	Artillerie- abteilung.	Oberst Dipl. Ing. Wöhlermann.	Artillery weapons, mortars and rocket projectors
Wa/Pruf. 5.	Pionier- abteilung.	Oberst Dipl. Ing. Stambach.	Pioneer weapons development.

Usual name or abbreviation.	Full name.	Chief personalities.	Functions.
"Pruf. Fest.	Pionierbataillon z. b. V.	?	Experimental and training of troops for "Taufum".
"Pruf. 6.	Festungsabteilung.	Oberst. Dipl. Ing. Teutsch Min. Rat Dipl. Ing. Kussner.	Erection of forts and gas defence of fortifications.
	Abt. fuer Motorisierung und Panzer.	Oberst Dipl. Ing. Holzheuer.	
		Oberst Dipl. Ing. Crohn. Dipl. Ing. Schmieto. Oberleutnant Zabel.	Gas defence for Panzers. Smoke for Panzers. Flares.
"Pruf. 8.	Ateilung fuer Optik.	Gen. Major Dipl. Ing. Rossmann. Oberreg. Baurat Dr. Gaertner. Reg. Baurat Dr. Braeunig	Infra-red research. Defogging.
Wa. Pruf. (Bulm)	Amtsgruppe fuer Ballistik und Munition.	Oberst Dipl. Ing. Schmidt.	
Wa. Pruf. (Bulm) 1	Abteilung fuer Munition Pulver und Sprengstoffe	Oberst Dipl. Ing. de Bouche Oberst. Dipl. Ing. Huck	Infantry grenades and weapons.

" Wap. ruf. (Bum) 3	Ballistische Abteilung	<p>Oberleutnant Vogel Dipl. Ing. Rogge. Oberst Dipl. Ing. Lorentz. Oberstleutnant Dipl. Ing. Otto. Min. Rat Dr. Wueelfken. Oberinspektor Gerloff</p> <p>Oberst Dr. Ing. Schubert. Min. Rat Dr. Thielo. Min. Rat Dr. Laugner Baurat Dr. Athen Baurat Dr. Kraus.</p> <p>Oberst Dr. Hirsch</p> <p>Oberstleutnant Dr. Ing. "Krober. Reg. Baurat Dr. Bitzken Dipl. Ing. Hess.</p> <p>Oberst Dielitz. Gen. Major Richter.</p>	<p>Artillery Shells (ironmongery) Hand grenades.</p> <p>Coloured smokes and signal munitions.</p> <p>Close combat material. Hollow charges. Flame throwers.</p> <p>Ballistic work, and preparation of range tables.</p>
" Wap. ruf. (Bum) 9	Abteilung fuer Gasschutz und Nebel		
" Wap. ruf. (Bum) 11	Abteilung fuer Raketenwaffen		Munitions for projectors, Ballistics and firing tables.
H. G. S. L. Spandau.	Heeresgass- chutz-Labora- torien Spandau.		Controlled by Prof. 9.
H. V. St. Raub- kammer.	Heeres-Ver- suchsstelle Raubkammer.		Controlled by Prof. 9

Usual name or abbreviation.	Full name.	Chief personalities.	Functions.
Wa/Mun.	Waffenamt Amtsguppe Munition	Gen. Major Dipl. Ing. Henrici	Supply and procurement of war gas storage and charging depots. Liaison with special committees of Speer Ministry.
Wa/Mun.	Munition-sabteilung.	Min. Rat Dr. Ehnarm Ob. Baurat Dr. Reinknecht Ob. Baurat Dr. Donath.	
Wa/W. u. G.	Amtsgruppe fuer Waffen und Geraet.		Procurement of gas defence equipment and textiles, and smoke apparatus. Liaison with special committees of the Speer Ministry.
Wa-WUG. 1.	Geraeteabteilung 1.	Oberstleutnant Buchler Major Lauscher.	
OKW/Ro.	Rohstoffabteilung.	?	General raw material and contingent questions for the Services.
OKW/Wiss.	Wissenschaftliche Abteilung	Min. Dir. Prof. Dr. Schumann Ob. Reg. Baurat Dr. Beyer.	Liaison with Reichsforschungsart. (State research advisory council) B. W. and insecticides.

Wa.	Arbeitsstab fuer Panzerabwehr	<p>Vorsitz: Oberst Kittel (Pruf 2) Vertreter: Gen. Der Panzertruppe, In 6, In 9. Pruf 1, Pruf 2, Pruf 4, Pruf 5, Pruf 6, Pruf 8, Pruf 9, Pruf 11. Panzertruppenschule.</p> <p>Gen. Major von Junck Vertreter: Pruf 5, Pruf Fest, Pruf 9 Wa-Chef Chem, WA-F.</p> <p>Gen. Major Dipl. Ing Zimmermann Gertreter: Pruf 1, Pruf 2, Pruf 4, Pruf 5, Pruf 9, Pruf 10 Pruf 11.</p> <p>Vertreten: Wa-Pruf, Wa-Pruf (Bum), Wa-Mun, Wa-WuG, Chef-Ing. Chef-Chem, Sparkommissaer and Umstellungs-beauftragte</p> <p>Vorsitz: Gen. d. Artillerie Leeb, mit der Vertretung beauftragt: Oberst Dr. Hirsch Sachbearbeiter: Min. Rat Dr. Ing Stantien.</p>	Panzer defence.
	Arbeitsstab fuer N-Stoff-Einsatz	<p>Search for new methods of employment of N-Stoff.</p>	
	Arbeitsstab fuer Zuenderentwicklung.	<p>New developments in fuzes especially highly sensitive fuzes and proximity fuzes.</p>	
	Arbeitsstab fuer Vereinfachung	<p>Economical substitutes. Simplification of designs and widening of tolerances.</p>	
	Arbeitsgemeinschaft "Blitzableiter".	<p>General questions of bacteriological warfare. Ditto.</p>	

Usual name or abbreviation.	Full name.	Chief personalities.	Functions.
		<p>Sektor 1: Prof. Dr. Blome, Prof. Dr. Rose (Lin. 14) Prof. Dr. Kliewe</p> <p>Sektor 2: Prof. Dr. Waldmann ein Veterinaer der Ven.</p> <p>Sektor 3: Ob. Reg. Baurat Dr. Beyer von OKW/Wiss. weiter vertreten: Prof. Schumann (WaF). Reichsforschungsrat, Amt fuer Volksgesundheit Volksernaehrungsamt Landwirtschaftliche Organisationen.</p>	<p>Section dealing with humans.</p> <p>Veterinary Section.</p> <p>Agricultural Section.</p>

S P E E R M I N I S T R Y

G. B. Chem.	<p>Verbindung zum Wa:</p> <p>Reichsstelle Chemie:</p>	<p>Oberst. Geist Berat Dipl. Ing. Gaul. Obersteutnant Dr. Ing. Singer.</p>	Raw material, general manufacturing questions.
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G.B.-Bau.	Gebietsbeauftragter und General- beauftragter Chemie	Prof. Dr. Krauch Staatsrat Schieber Dr. Brudy	
	Planungsamt:	Gen. Major Dipl. Ing. Waeger.	Planning and building of new installations.
	Generalbevolläch- tigter für das Bauwesen	?	Priorities for material for new installa- tions. Allocation of labour.
	Arbeitsausschuss C.	Vorsitz: Dr. Ambros (I.G.) Dr. Ing. Klenk Vertretern von: In. 9 Prüf 9, Mun. 3, OKW/Ro, G.B. Chem, Dienststelle Prof. Brandt.	General war gas and intermediates manufacture and installations pertaining thereto. Decontaminants.
	Arbeitsausschuss Gasschutzgeraete	Vorsitz: Prof. Quasebart Vertreter von: In. 9, Prüf 9, WdG 1, OKW/Ro, Lin. 13, und Prof. Brandt.	Gas defence equipment, Individual and collective. Activated charcoal.
	Arbeitsausschuss Nebelstoffe	Vorsitz: Dr. Wurster (I.G.) Vertreter von: In. 9, Prüf. 9, Mun. 3, Lin. 13. OKW/Ro.	Smokes for the Services and for civilian air raid defence.

Usual name or abbreviation.	Full name.	Chief personalities.	Functions.
	Areitsausschuss Nebelgeraet	Direktor Flett (Hagemug, Kiel) Direktor Dr. Ing. Scholler (P.I.W. Barth). Direktor Dr. von Gagern (Minimax) Vertreter von: In. 9, Prof 9, Mun. 3, Wdg. 1, Lin. 13 OKW/Ro.	Smoke materials - smoke generators and thermal generators. Smoke equipment.

OTHER ESTABLISHMENTS

	Reichsforschungsrat	Vorsitz: Prof. Dr. Thiessen Prof. Dr. Blome Prof. Dr. Planck Staatsrat Schieber Prof. Menzel Min. Dir. Prof. Dr. Schumann and many others.	Advisory research council.
C.T.R.	Chemisch Technische Reichsanstalt	Praesident: Dr. Remarski Dr. Roedig Dr. Hoffmann Reg. Dr. Ing. Dithmar Dr. Pinnow Dr. Luchsinger.	Stability of powders. Storage, research, corrosion, materials research. Safety directives. Smoke acids.
R.W.M.	Reichswirtschaftsministerium.	Min. Rat Dr. Taeglich	Factory and transport safety questions.

R. P. A.	Reichsanstalt fuer Luft- und Wasserguete	Prof. Dr. Haase.	Researches in decontaminating drinking water.
Dienst- elle Prof. Brandt.	Reichspatentamt General bevoll- mächtigter fuer das Gesundheitswesen	--- Prof. Dr. Brandt. Oberstleutnant Bode (Heer) Min. Rat Milenz (Lin. 13) Vertreten: Ministerium Speer Wa., Prüf 9 WuG1, Mun. 3, In. 9. General der Nebeltruppe, Lin. 13, Sin., Lin. 14, Dr. Ambros (IG). Prof. Dr. Quasebart.	General patent questions. Open and secret patents. Patent indices. Co-ordination of military and civil gas defence. Co-ordinates military and civil requirements for manufacture, raw materials and labour. Adviser to the " <u>Fuehrer</u> " in gas defence questions.

N A V Y.

M. G. L. I.	Marine Gaschutz and Luftschutz- inspektion.	Kapt. z. See Bentlage Freg. Kapt. Dr. Tobias Kerv. Kapt. Dr. Hirasch Kerv. Kapt. Grupe.	Gas defence on board ship. Gas defence equipment smoke. (Analogous to In. 9 for Army)
M. G. S. S.	Marine Gasschutz- schule.	---	Analogous to Army Gas defence School in Celle.
OKA/Mar. Ruest/ AWA/A/I.	Oberkommando der Marine Marine-Ruestung, Marine-Waffenamt,	Kapt. z. See Dipl. Ing. Meusemann Reg. Baurat Dr. Ide.	Artillery munitions (Meppen) war gas questions (Flön) analogous to Prüf. 9.

Usual name or abbreviation.	Full name.	Chief personalities.	Functions.
OKM/Mar. Ruest/ AWA/C.	Oberkommando der Marine-Ruestung, Marine-Waffenamt, Abt. Beschaffung.	---	Analogous to Wa. Mun 3 and WuG 1.
C. P. V. A.	Chemisch Physi- kalische Ver- suchsanstalt.	Ober Reg. Rat. Dr. Ulrich Mueller. Reg. Bau Rat Dr. Hennings. Dr. Nedopil Dr. Wiese (Frueher Prof. 9)	Chemical and war gas questions. Analogous partly to laboratories 6 B1 and 6 C1 in Spandau for special navy use. General Meteorology. Special meteorological questions.
	Marine Wetter- dienst	Reg. Rat Dr. Moll Reg. Rat Prof. Dr. Krull Reg. Rat Dr. Kornemann	

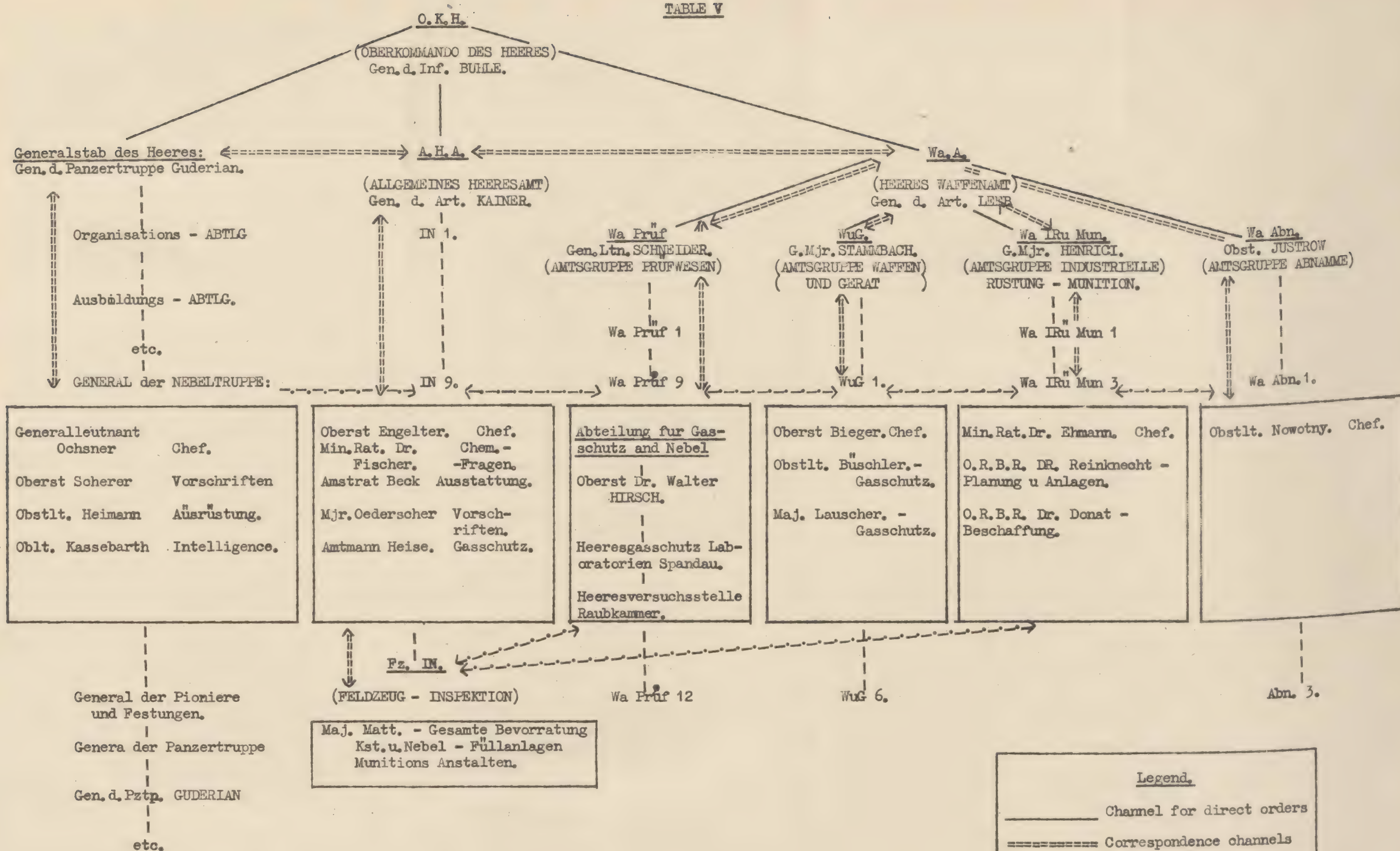
L U F T W A F F E

OKL/TLR/FLE	Oberkommando der Luftwaffe/Tech- nische Lufttrues- tung/Fliegerische Entwicklung.	Gen. Ing. Marquardt Flieger Stabs Ing. Dipl. Ing. Schiedler Flieger Stabs Ing. Dr. Preiss Flieger Stabs Ing. Dipl. Ing. Gruner Flieger Stabs Ing. Dr. Löwa	War gas and smoke. Development of air requirements in co- operation with Prüf. 9.
OKL/TLR/FLB	Oberkommando der Luftwaffe/Tech- nische Lufttrues- tung/Flieger- materialbeschaffung	Flieger Ob. Ing. Stein.	Provision. Analogous Mun 3 and WuG 1.

K.d.E.	Kommandeur der Erprobungsstellen	---	General trials or air force material.
E-Steele O.Lw. Munster-Nord.	Erprobungsstelle der Luftwaffe Munster-Nord.	Flieger Stabs Ing.Dr. Pritzkow Flieger Stabs Ing.Dr. Muttone Flieger Stabs Ing.Dr. Zuschrott Flieger Stabs Ing.Dr. Frank.	Development and trials in co-operation with Pr"uf.9. Analogous to Army experimental station at Raubkammer.
R.d.L./Lin. 13.	Reichsminister der Luftfahrt/Luftwaffeninspektion 13.	Min.Dir.Dr.Knipfer Min.Dri.Lindner Min.Rat.Dr. Mielenz Ob.Reg.Chemie Rat Dr.Stobwasser Ob.Reg.Chemie Rat Dr. Ensfellner Reg.Chemie Rat Dr.Tubben	Air raid defence for civilians.
R.d.L./Lin. 14.	Reichsminister der Luftwaffeninspektion 14.	Oberstarzt Prof.Dr. Rose	Smoke screening of industries, towns, etc. Development of civilian masks - somewhat analogous to In.9. Medical questions for civilian gas defence; analogous to Sin.
R.A.L.S.	Reichsanstalt der Luftwaffe fuer Luftschutz	Gen.Leutnant Stubenrauch Oberst Lukaseder (6) Reg.Chemie Rat Dr.Graf Degenfeld Reg.Chemie Rat Dr. Daehlmann.	Experimental and trials of civilian gas defence.

Usual name or abbreviation.	Full name.	Chief personalities.	Functions.
	<p>"Hoherer Kommandue fuer Truppengasschuts."</p> <p>Gasschuttschule der Luftwaffe</p> <p>Reichsamt fuer Wetterdienst</p> <p>Chef Wetterdienst.</p> <p>Meteorologische Observatorium des Reichsaamtes fuer Wetterdienst.</p> <p>Forstschutzstaffel der Luftwaffe.</p>	<p>Gen. Leutnant Laule Oberst (W) Geissler Oberstleutnant Kirchner Major Scheiner (O)</p> <p>---</p> <p>---</p> <p>---</p> <p>Min. Rat Prof. Dr. Koschmieder.</p> <p>Oberst von Borstell.</p>	<p>Directives and tactics of gas defence and offence for the Luftwaffe. Analogous to general of smoke troops and In. 9 of the Army.</p> <p>Analogous to Army gas defence School in Celle.</p> <p>Central control of weather bureaux for the whole Reichs.</p> <p>Central control of weather bureaux for the wehrmacht. Special weather bureau for Luftwaffe.</p> <p>Central meteorological office.</p> <p>Post eradiction research and development.</p>

TABLE V



W a A.

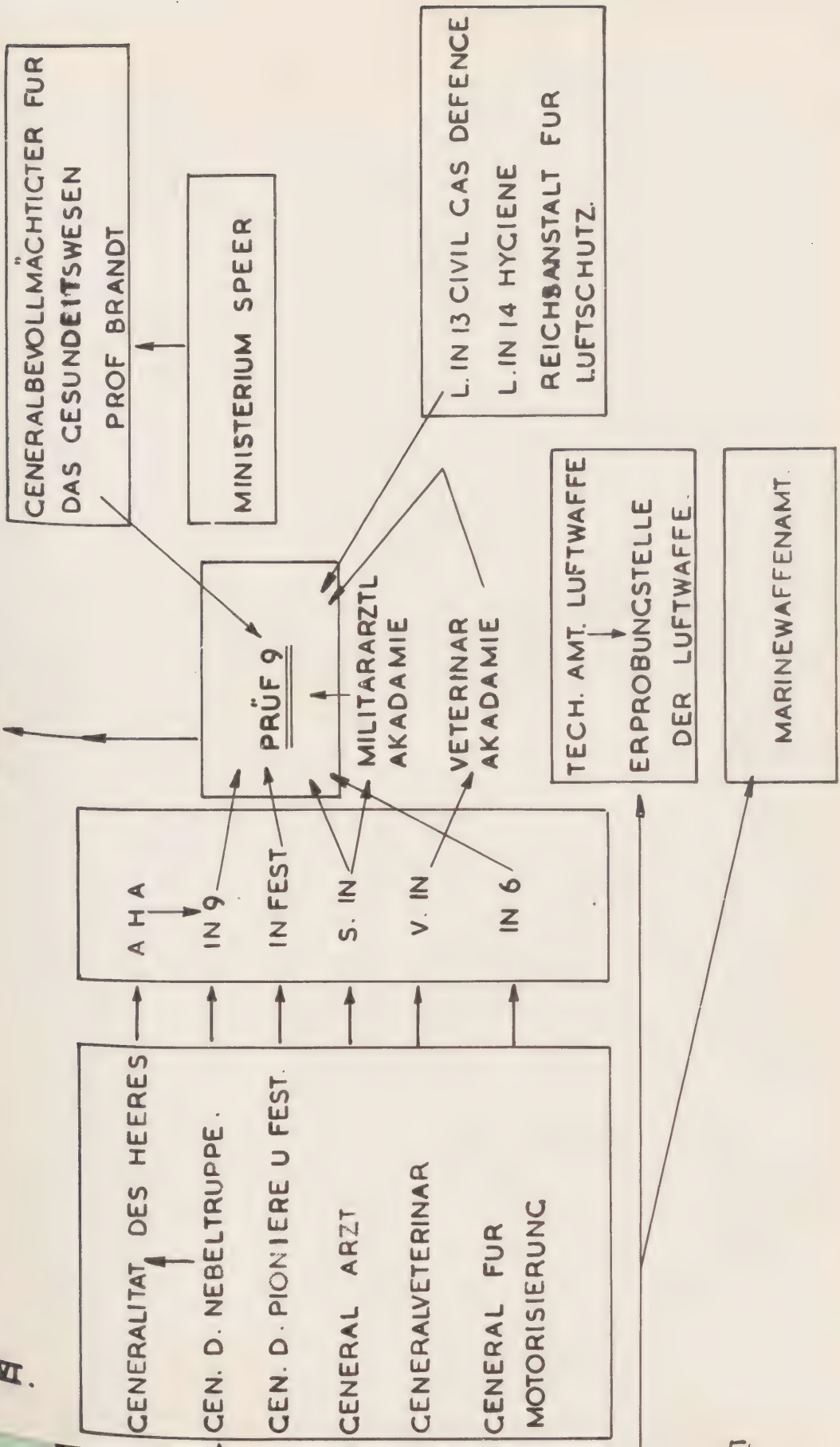


TABLE VII

Personalities required for interrogation

Name	Office	Functions
Prof. Fritz Wirth	Wa Prüf. 9. III	Decontamination and Gas Protection.
RBR Dr. Schreiner	Wa Prüf. 9. VIa	Shell design.
Oberstabartz Prof. Dr. Wolfgang Wirth	Wa Prüf. 9. VII	Toxicology.
Oberstabartz Prof. Kliewe,	Wa Prüf. 9. VIIc	Hygiene and Bacteriology.
Reg.B. Dr. Gebhardt.	Wa Prüf. 9. VIII(b)	Chemistry of Manufacture.
Min.Rat.Dr.Stantien.	Wa Prüf. 9. X	Insecticides, incendiaries etc.
Oberstabartz Dr. Reinecke.	Wa Prüf. 9. XIII.	Veterinary.
O.B. Dr. Böttger	Spandau. F.1.	Chemical synthesis.
Dr. Wolf.	Spandau. F.1.	Analytical Chemical.
Dr. Wolf, Johannes.	Spandau. F.2.	Sarin and Tabun work.
Prof. Jung.	Spandau. F.3.	Microchemical and Physicochemical.
Oberst von Sicherer.	Prüf. 9.	General C.W.
O.B.R. Dr. Zeumer.	Spandau. F.4.	Measurements or concentrat- ions on Films etc.
O.B. Dr. Koch.	Spandau. II.L.	Personal Protection.
Dr. Mai.	Spandau. II.L.	Personal Protection.
O.B. Dr. Schultz- Overberg.	Spandau. III.L.	Collective Protection.
Dr. Schaeffler.	Spandau. III.b.L.	Detection and Recognition.

O.B. Dr. Stuhldreer.	Spandau. VI.a.L.	Dusts, sprays and smokes.
Dr. Fusting.	Spandau. Lab.2.	Organic chemicals.
Oberstartz Dr. Sextel.	Spandau. VII.L.	Toxicology.
Dr. Dörken.	Spandau. VIII.L.	Semi-Technical Scale Plant
Dr. Niggemeier.	-do-	-do-
Fl. Stabs. Mg. Dr. Pritzkow.	Erprobungstelle der Luftwaffe.	Air force weapons.
Fl. Stabsing. Dr. Muttone.	-do-	-do-
Fl. Stabsing Gruner.	-do-	Smoke and Chemical aspects of S.C.I. use.
Fl. Stabsing Zuschrott.	-do-	Maintenance of S.C.I. and i/c Workshops.
Fl. Haupting Dr. Frank.	Erprobungstelle der Luftwaffe.	Air Force Weapons.
Fl. Haupting Dr. Marthaler.	-do-	Air Force Weapons.
Fl. Ing. Beckert.	-do-	Air Force Weapons.
Prof. Wimmer.	Strasburg University.	Toxicology.
Prof. Picker.	-do-	-do-
Prof. Flury.	Wurzburg University.	-do-
Generalleutnant Ochsner	General der Nebeltruppe. (General of smoke or gas troops)	Gas policy in Army.
Oberstleutnant Heimann.	General Staff.	-do-
Oberleutnant Kassebarth.	-do-	-do-

Oberstleutnant Dr. Korbler	Inspekteur der Panzertruppe.	Gas protection for tanks and motorised units.
Oberst Engelter.	Inspektion 9.	Tactical questions and approval of weapons for.
Major Prohaska	-do-	Smoke (gas) troops.
Min.Rat. Dr. Fischer.	-do-	-do-
Min. Dir. Prof. Dr. Schumann.	WaF.	Various physical research connected with C.W. May have connections with S.S.
Oberst. Dipl. Ing. Holzheuer.	Prüf. 6.	Gas protection and smoke for tanks - technical develop- ment.
Oberst. Dipl. Ing. Crohn.	-do-	-do-
Dipl. Ing. Schmieto.	-do-	-do-
Oberleutnant Zabel.	-do-	-do-
Oberst. Dipl. Ing. Lorentz.	Wa Prüf. (BuM) 1	Coloured smokes, and signal ammunition.
Min. Rat. Dr. Ehmman.	Wa/Mun.	Supply and procurement of war gas factories in liaison with Ministerium Speer.
Ob. Baurat Dr. Reinknecht.	-do-	-do-
Ob. Baurat Dr. Donath.	-do-	-do-
Oberstleutnant Matt.	Feldzeug-Inspek- tion.	Storage of gas munitions.
Gen. Major von Junck.	Arbeitsstab für N-Stoff Einsatz.	Use of N-Stoff (chlorine trifluoride).
Prof. Quasebart.	Arbeitsausschuss Gasschutz-geraete. (Ministerium Speer)	Production of activated charcoal.

Prof. Dr. Haase.	Reichsanstalt fuer Luft-und Wasser- guete.	Decontamination of drinking water.
Prof. Dr. Brandt.	General bevoll- machtgter fuer has Gesundheit- swesen.	Coordination of military and civil gas defence.
Flieger Stabs. Ing. Dipl. Ing. Schiedier.	Luftwaffe high command technical	Air requirements for war gas and smoke.
Flieger Stabs. Ing. Dr. Preiss.	-do-	-do-
Flieger Stabs. Ing. Dipl. Ing. Gruner.	-do-	-do-
Flieger Stabs. Ing. Dr. Lova	-do-	-do-
Min. Dir. Dr. Knipfer	Reichsminister der Luftfahrt/ Luftwaffen inspektion 13.	Civilian air raid gas defence.
Min. Dir. Lindner.	-do-	-do-
Min. Rat. Dr. Mielenz.	-do-	-do-
Ob. Reg. Chemia Rat. Dr. Stobwasser	-do-	-do-
Ob. Reg. Chemia Rat. Dr. Ensfellner.	-do-	-do-
Reg. Chemia Rat. Dr. Tubben	-do-	-do-
Oberstarzt Prof. Dr. Rose.	Reichsminister der Luftfahrt/ Luftwaffen- inspektion 14.	Smoke screening of industrial targets.
Oberst. Lukaseder.	Reichsanstalt der Luftwaffe fuer Luftschutz.	Experiments on air raid defence, including gas defence
Reg. Chemie Rat. Dr. Graf. Degenfeld.	-do-	-do-

Reg. Chemia Rat. Dr. Daehlmann.	Reichsanstalt der Luftwaffe für Luftschutz.	Experiments on air-raid defence including gas defence.
Oberst. (W) Geissler	" Hoherer Kommando FÜR Truppengas- schutz.	Tactics of gas defence and offence in Luftwaffe.
Oberstleutnant Kirchner.	-do-	-do-
Major Scheiner.	-do-	-do-
Oberst von Borstell.	Forstschutzstaffel der Luftwaffe.	Pest eradication.
Forstmeister Dr. Schwerdtfeger	Forstschutzstaffel der Luftwaffe.	Pest eradication.
O.R.G.R. Dr. Beyer	OKW/Wiss.	Insecticides.
Obergruppenführer Dr. Schwab.	SS	Manufacture of N-Stoff (Chlorine trifluoride)

Investigation of Chemical Warfare Installations
in the Munsterlager Area, including Raubkammer

APPENDIX I. - FIELD TRIALS ORGANIZATION

1. Introduction.
 2. Ranges.
 3. Messhafter (Sampling chambers).
 4. Vauzet Turm (Vauzet Tower).
 5. Field trials preparation Section (R.Ia).
 6. Photographic Section (R.I.b).
 7. Analytical Section (R.II).
 8. Meteorological Section.
 9. Organization of field trials.
 10. Field trial technique.
 11. Analytical methods.
 12. Interpretation of results of field trials.
 13. Results of field trials.
 14. Summary and appreciation of trials organization.
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APPENDIX I.

Field Trials Organisation

1. Introduction

This Appendix gives a description of the range at Raubkammer and of the equipment and laboratories connected with it. It also includes details of the organisation of field trials, of the sampling and analytical methods employed. A note on the meteorological work carried out at Raubkammer is included.

The following were interrogated for the purpose of compiling this Appendix.

<u>Name</u>	<u>Rank</u>	<u>Department</u>
Hirsch	Oberst	Head of Wa Prüf 9.
Weinberg	Min. Rat.	Head of Gruppe VI.
Prüssener	Oberstabsarzt	Gruppe VII b.
Nobbe	O.R.B.R.	Gruppe VI f.
Flügel	Oberinspekteur.	Gruppe VI b.(4).
Weinzierl	O.R.B.R.	R.II.
Ulm		F.2. Spandau.
Janssen	O.R.B.R.	Gruppe I.e.
Zachow	Angest	R.1.
Dietz	O.R.B.R.	R.IV.
Sleumer	Sergeant	R.I.
Gritsche	Major	V. b.
Schultz	Werkmeister	R.1.
Döll	R.B.	W.A.VI.

The Raubkammer range and the laboratories connected with it are shortly to be used by a field trial group for a series of trials in which various German munition will be assessed by Allied and by German field assessment methods. When these trials are complete it will no doubt be possible to supplement the information given herein in a number of details, and to give a more considered appreciation of German field technique.

2. Ranges

The ranges (see Fig.I. of Report) are situated just North of Munster and are roughly rectangular in shape, the corners being at the following map references 587019, 539974 (Sheet 2926 Brelch), 596911 (Sheet 3026 Munster), 701950 (Sheet 2927 Wriedel). The sides of the rectangle are about 16 km. x 8 km. and the total area 10100 ha. The area is mostly covered with coniferous forest, but there is a tract of open heath land about 3 km. x 1.5 km. in the centre of the area, in which most of the field sampling lay-outs are contained. The whole range is flat and level. Artillery can be fired up to a range of 10 km. without danger. The distance from the centre of the main range to the nearest point of the boundary is 3.5 km.

In the open heath land there are several permanent sampling lay-outs marked by posts and coloured screens. One of them was mainly for trials with aircraft bombs. This has no permanent observation post, but observers are provided with portable shelters of about 10 mm. armour plate. Another, the "Schienenkreis", which is used for static trials is provided with miniature railway lines on circles 15, 25 and 50 m. in diameter along which sampling apparatus can be run. Others used for fired shell are provided with large pillboxes of concrete thick enough to withstand a direct hit, and capable of holding 50 to 100 people. The observation rooms are gas proofed and fitted with a collective protection apparatus. There are three of these pill-boxes, which are, or were, elaborately camouflaged.



Portable Shelter.



Trolley for Sampling Apparatus.



Camouflaged concrete Pillbox.



Concrete Pillbox.

3. Messhäuser (Sampling chambers)

The oldest of the Messhäuser is rectangular, about 30 m. x 30 m. in area, and 20 m. high, the volume being 18,000 cu.m. The floor is of sand and there are walls of $\frac{3}{4}$ " boarding on a steel framework. There is a central fan in the roof and other fans arranged at the foot of the walls for blowing in fresh air at the conclusion of a trial. Samplers and animals were placed on the floor, and suspended from the roof at a height of 7 or 8 m. The Messhaus was used for sampling gun and small arms shell. After the explosion, the atmosphere was mixed for two minutes and the samplers and animals were then introduced. After each trial the timbers were repaired by patching. It was ascertained that when computing results an arbitrary 50 per cent allowance was made for losses on the walls of the chamber.



Small Messhaus.

The construction of the newer Messhaus had not yet been completed, the electric wiring requiring to be finished. It is duodecagonal in shape, with a diam. of 50 m. and is 27 m. high, the capacity being 50,000 cu.m. The construction is much the same as that of the older one, except that the floor is of concrete, since it was found that too much dust was raised in the old Messhaus. Besides providing for sampling apparatus suspended from the roof, two cages about half way up the walls enable animals and samples to be introduced. Three fans in the roof were used for mixing, and six fans at the foot of the walls for blowing in fresh air at the conclusion of a trial.



Large Messhaus.

4. Vauzet Turm. (Vauzet Tower).

This consists of a strongly built steel tower, about 10 m. high, on which is mounted a 105 or 150 mm. gun on a rotating platform. The elevation of the gun can be depressed and the charge adjusted in such a way that the shell strikes the ground about 50 m. from the base of the tower at a velocity corresponding to the striking velocity of a shell fired normally. The direction of fire was with the wind. The tower is based on a concrete foundation, within which is a shelter containing selectors for controlling chemical sampling and provided with four small domed observation slits.



Vauzet Turm.



Vauzet Turm.

The concrete shelter had not recently been used by observers, portable steel shelters being used instead.

A concrete lined trench encircles the tower at a distance of 50m. This about 60 cm. deep and wide enough to accommodate a miniature gauge railway line along which trolleys containing sampling apparatus can be positioned. Provisions for further sampling points further down-wind had been made.

Detailed drawings showing the construction of the Vauzet Turm are in preparation, and copies will be available to all interested departments.



Vauzet Turm - Sampling Trench.

5. Field Trials Preparation Section (RIa).

This section shared a building with RIb - Photography. It contains, besides offices, the following:-

- (i) A room containing stocks of cables and control boxes.
- (ii) An injector store room containing a stock of 230 electrically operated injectors, with rack space for 330.

- (iii) An injector preparation and repair room containing a stock of spare parts and five repair benches.
- (iv) A store room for miscellaneous engineering equipment.
- (v) An air bottle charging room.
- (vi) A small room accommodating a watch maker.
- (vii) An attic containing stakes of all kinds, both steel and wooden, cards with treated surfaces, pressure gauges, control boxes, cables, etc.



Field Trials Preparation
and Photography Sections (RI).

The injectors most recently used were electrically operated by means of a 12 volt battery which was buried close to the sampling points. This was actuated by a relay switched on from a control point worked by a 40 volt battery. The batteries were of the steel type and did not deteriorate if left unattended. The air bottle of the injector had a capacity of 2 litres and was charged to 150 atmos.

Before an injector was taken out into the field it was adjusted by means of a key which operated on the collar of the reducing valve to give the correct rate of flow through the bubbler with which it was to be used. The rate of flow was measured by an ordinary rotameter. The usual rate of flow was 40 l/min., obtained with an H type injector tube. For 80 l/min. an F. type was used and for 10 l/min., a V-type. At 40 l/min., the injector would provide a constant flow for 20 minutes.

In firing trials, the sectors of injectors were operated at a distance by a control switch board. Wiring of the injectors was in parallel so that the contacting of a single switch would set in action a number of injectors simultaneously. The switch was connected in series with a 40-volt battery, and a relay at the sampling position. The relay closed the circuits, all in parallel, to the magnetic valves of the injectors. These valves worked off of a 12-volt battery buried in the ground, but the actual operating voltage could be as low as 9 volts; 7 volts only partially opens the valves.

6. Photographic Section. (R1b)

The photographic section was well equipped for both still and motion picture photography. It consisted essentially of a large main laboratory along either side of which was grouped a number of smaller rooms. On one side there was a negative store, an office, a well-equipped copying room, a developing room for colour photographs and films, and a titling and washing room. On the other side were four dark rooms for developing and printing and a stock room. The main laboratory was used for drying, cutting, finishing, etc.

The equipment was of standard type and does not call for special comment. It is evident that both 16 and 35 mm. motion pictures were taken and a projector for the latter was found. No cameras were found, and most negatives had been destroyed although a number of old ones had been buried. Some of these have been retrieved for examination.

There was a large studio, with skylight illumination, in the attic of the building.

Colour Photographs

Colour prints were prepared either by means of a special camera which took three photographs simultaneously or else from enlargements from Agfa colour transparencies taken with a Leica camera.

In the first case, three pictures were taken simultaneously in a special camera made by Berrpohl (Berlin). The camera was of the duplex

Type, one lens (F3.5) being used for focussing on a ground glass screen fitted with a viewing eyepiece, and the other, for projecting the image on the three plates. One plate received the image direct and the other two, set at right angles to it, via reflecting plates. Evidently the optical system was very carefully adjusted so that each plate received equal illumination, and each image was perfectly in focus. A red, green and blue filter was placed in front of each plate respectively. Agfa Panchromatic No.12 were used (between 1/4 and 1/2 plate size).

After development under careful temperature control, enlargements of each negative were made on film (Matrizenfilm Coloprint, Agfa). The films were bleached in a mixture of 10 per cent potassium ferricyanide and 10 per cent sodium thiosulphate, and then dipped in a dye solution (composition not known) appropriate to the colour filter used. After sufficient dye had been taken up, and this was a matter of judgment, the transparencies were pressed in turn on to thick paper which had previously been wetted. Holes were punched in the film so that exact superimposition of the three primary colour pictures could be obtained. In this way the colour was stripped off the films and the final colour print built up. The whole process had been developed by Colorprint, Vienna.

In the second case, enlargements were prepared from the Leica transparency through primary colour filters, positives were made and the process then followed that outlined above.

7. Analytical Section. (R II).

This contained three laboratories 20 ft. x 25 ft. and one 20 ft. x 45 ft., which all appeared to be well equipped analytical laboratories of a standard type. There was little indication of any research proceeding on either methods of analysis or any other aspect of chemical warfare. Among the sampling apparatus seen were the following:-

- (a) Several hundred large bubblers of about 500 cc. capacity containing a sintered glass spreader, and a number of field carriers. The use of these bubblers is described in paragraph 10.
- (b) Several hundred sintered glass filters for sampling toxic smokes.

- (c) About 90 kineographs. These consisted of airtight bakelite cases containing uncoated film which was passed in front of a metal jet communicating with the outside air. The film could be driven electrically or by hand. Suction could be applied to a tube leading from the case and in this way a continuous record from a smoke cloud could be obtained on the film. The kineographs were made by the firm of Guya, Berlin. Some were found containing traces of DM.
- (d) Wide-mouthed stoppered glass jars for earth sampling.
- (e) A number of French recorders, apparently for phosgene, manufactured by the Soc. Anon. Les Appareils Controlleurs in 1939.

Samples of the apparatus tested above are being evacuated.

Apart from the kineograph, no trace of physical sampling apparatus was found.

Further rooms included a preparation room 20 ft. x 25 ft. a director's office, with adjoining office, two balance rooms and a shower room.

There were open balconies at each end of the building.

In the basement there was a dark room and large reserves of equipment. The loft contained further stores and also the fans and counterweights for the fume cupboards.



Analytical Section (R II).

8. Meteorological Section. (Wetterdienst Abteilung VI).

The meteorological building and adjacent tower are situated in a clearing in a pine wood just outside the northern boundary fence of the main closed area and a small distance to the west of the intersection of the main Brelow road with the General Becker Strasse. Strictly speaking the Section was not part of Raubkammer, but served all military units in the neighbourhood, although all meteorological information required by Raubkammer was supplied.

The section was housed in a low brick building about 50 yards long. There are ten rooms arranged on either side of a central corridor. On one side there were three offices, an instrument store and a preparation room. On the other side there was a recording and plotting room, a drawing office, a lecture and cine room, a room with sleeping bunks and lavatories.

The instrument room contained standard meteorological equipment including cinemometers, wind direction meters, psychrometers, theodolites for pilot balloon observations, radio sondes, etc. Certain special instruments for C.W. meteorology were retrieved and these are discussed below.

In the main recording and plotting room were situated the wind and direction recorders for instruments on the tower. Charts showing complete climatological records over several years were found. The observation log books were intact and are being sent back to U.K. The last observation was taken on 9.4.45. A few weather maps were also found.

The tower adjacent to the meteorological building was constructed of wood and was some 80 ft. high. At the base there was a small wooden building used as a store for heavy materials. The tower was some 20 ft. higher than the surrounding trees. At the top there was a cup anemometer and wind direction vane connected to the recording gear in the main building. On the other side of the building there was the usual Stephenson screen in a small enclosure.

The head of the Section was Major DOLL (Regierungs Baurat), who was interrogated. His deputy was Hauptmann Braun, but his whereabouts were unknown. Other staff consisted of 5 civilians (3 women) and 5 or more soldiers. Military personnel were constantly being changed.

A great deal of the work of the section appeared to be devoted to taking routine climatological observations and certain special observations in connection with field experiments. Meteorological research as applied to C.W. was until recently almost non-existent.

Weather maps were prepared every day and a forecast was sent to the Kommandantur and R.VI. Information to enable the weather maps to be prepared was received over the telephone from Fassberg or Hanover. There was no teleprinter service. Temperature, pressure and humidity measurements in the upper atmosphere were obtained from Unterluss, Hanover, Fassberg or Hanover. If these were not available, radio sonde measurements were made at Raubkammer. All the necessary weather information required by the Nebeltruppen and by the gunners on the ranges could be supplied.

Measurements were made of temperature, wind speed and direction, and relative humidity at ground level and at 2 m. in all field experiments. When more detailed information was required wind profile measurements over intervals of 5 minutes were made by observations at 0, 1/4, 1/2, 1, 2, 3 and 5 m. by means of small Fuess cup anemometers. These were arranged alternately on either side of a wooden mast and each was fitted with a starting and stopping electromagnet worked off 6-volts. The minimum wind speed registered by the anemometers was 0.8 m/sec. Specimens are being sent to U.K.

Temperature and humidity measurements were also made at 0, 2, 8 and 16 m. by means of special Assmann psychrometers developed by the Navy. The thermometers had a U-bend and constriction above the bulb; when inverted the mercury broke, always at the same spot, and filled the top end of the stem. Being of the clinical type the reading then did not change with small variation of outside temperature. The procedure in taking temperature gradient measurements was to hoist the psychrometers up a steel telescopic mast to the required height and, at the required moment, to invert them by a string mechanism and then lower them, when the readings could be made at leisure. Specimens are being sent to U.K.

Reports of meteorological observations were sent to R II and Gr VI (Wa Prüf 9) for the information of Dr. Schmiess and Dr. Schreiner. Certain of the observations were also sent to Prof. Krull and Prof. Bartels at the Meteorologische Institut, Berlin. No correlation between concentrations found during field trials and meteorological conditions were done in the meteorological section.

The Germans obtained through the French information of British work on diffusion of gases through the atmosphere and the mathematical theories of atmospheric turbulence which had been put forward and which had led to the development of the concentration slide rule. They had seen the Porton Memoranda prepared for the Anglo-French conversations and were particularly interested in No.6 dealing with Meteorology. They had also captured copies of the first edition of the Chemical Warfare Pocket Book, but had failed to acquire a slide rule. They had also noted Sutton's work published in the Proceedings of the Royal Society.

As a result of the Porton work, a study of diffusion of gases in the atmosphere was made by the Reichsanstalt für Meteorologie and other institutes and it was concluded that the British work and conclusions were correct. Various other formulae due to Walker, Prentiss and Stampe were tried in order to fit the results of field experiments. Those due to Walker and Prentiss fitted fairly well, but Stampe's formula was considered to be quite useless.

It was not, however, until February 1945 that any serious attempt was made to investigate the travel of gas clouds in relation to turbulence. Dr. Kaiser of VI e L started work at Raubkammer at that time and one of his first experiments was to carry out tests of a form of bi-directional wind vane known as the Raumliche Windfahne. Apparently a description of the Porton vane had been seen in the Porton Memorandum, but no illustration and this was an attempt to imitate the instrument. The German version was much larger and must have suffered from inertia effects. The Raubkammer instrument is being sent to U.K. with examples of some of the traces. The instrument itself was designed by Dr. Kölze of the Army Meteorological Service, Berlin and the programme of proposed trials with it is being sent back to U.K.

Failing a slide rule, a number of ~~nomograms~~ nomograms were prepared by Dr. Wickhardt from which concentrations could be read off under different conditions. No specimens of the nomograms or details of the formulae in which they were based have been obtained; probably they were burned. Experiments were in hand to check the validity of the nomograms, but they were incomplete and no results were available.

No systematic measurements were made in connection with the development of smoke generators and comparisons were done on empirical lines. Some work had been started on the measurement of the angle of the cone of smoke from a generator and the screening length. The screening by it was defined as the axial distance from the source at which a man standing on one side of the smoke screen would just fail

to see a man on the other side. Concentrations were also measured, but again no records of results were available.

No work on area screens had been done at Raubkammer, this being the concern of the Luftwaffe. A manual on visibility and screening from the air had been prepared by the Reichsamt für Wetterdienst, but this was purely of a practical nature. There was no evidence of any work on the fundamental factors involved in the screening process.

As far as the evidence from Raubkammer goes, it is apparent that the German knowledge of the travel of gas and smoke clouds was in a very elementary state and lagged far behind the British and Americans both on the theoretical and practical sides.

9. Organization of Field Trials

Raubkammer was responsible only for the execution of field trials. The initiative in proposing and planning field trials lay entirely with Wa Prüf 9. There was no one section of Wa Prüf 9 which was exclusively concerned in field-trials, except Group VII b. although Gruppe X had as part of its duties the development of field trial technique. Group VII b was however only concerned with the physiological aspects, and did not undertake the planning of any other aspects of trials. The referant of any section, when he decided a trial was required, would send to Raubkammer a proforma giving the time, date and place of the trial, a list of the visitors attending, a brief description of the procedure required, and sometimes, but not always, the purpose of the trial. The instructions were by no means detailed; the trials were nearly always on stereotyped lines, conducted at the fixed sampling points and using standard layouts for chemical and animal sampling. There was an informal co-operation between the various sections of Wa Prüf 9 in arranging their trials to avoid clashes of dates, and to ensure that all equipment, animals, etc. were available, Raubkammer itself apparently not being consulted. The safety of a trial was the responsibility of the head of Gruppe VI and it does not appear that the Commandant of Raubkammer had any standing whatever in this matter, or any power of veto over a trial for this or any other reason. Representatives of Wa Prüf 9 came to Raubkammer and took complete charge of the trials from all aspects. If the weather on the appointed day was too windy or wet the trial would be postponed from day to day until the conditions were favourable, the Wa Prüf 9 representatives staying to see it through. Postponement was, however, rare, as exact meteorological conditions were seldom specified, although these were recorded.

When a trial had been completed, the results from individual sampling points were worked out in the Raubkammer laboratories, and the results entered on charts, blanks of which were available. All results were collected by the Wa Prüf 9 representative who correlated them and wrote a draft report which was circulated among his colleagues in Wa Prüf 9. Criticisms were made in an informal manner and the final report issued. Again Raubkammer was not consulted during the interpretation of the results nor was it usually informed of the outcome of the trial.

10. Field trial technique

The analytical methods used in field trials were developed in Spandau sections F 2 and IIb working under the direction of Gruppe X. This Gruppe, whose head was Dr. Stantien, formerly of Prüf S, was at an early period given the responsibility of developing field assessment methods much more accurate than those of the last war. The principle apparatus used for sampling vapours were 500 cc bubblers having sintered glass spreaders, known as Kolliker bottles, which were marketed by Schott und Genossen of Jena and are described in Chem Fabrik 6 299 (1933). Air, drawn in by injector apparatus, can be passed through these bubblers at rates varying from 15 to 40 L per minute, the most usual rate being 40 L per minute. (The reagents used and the methods of estimation are given in paragraph 11). Sampling took place at various heights, the most usual ones being 30 cm. and 150 cm. Measurements of concentrations could continue over a period of 10 or 20 minutes or, in some trials, banks of bubblers were run for short periods in succession. Usually the bubblers were opened just before the start of an experiment, but on some occasions the starting of the bubblers was delayed until the calculated time for the initial cloud to drift to the sampling point had elapsed, thus obtaining the peak concentration. The most usual layout of bubblers for static trials was in circles 30, 50, 75 and 100 metres from the bursting area, 16 bubblers to a circle and staggered between circles. When shell were tested, only the downwind quadrant of the circle was used, but for bombs, the whole circle. A similar arrangement was used for shell trials at the Vauzet Turm. When shell fired from guns were assessed the bubblers were arranged in 5 rows of 20, each 10 metres apart, just downwind of the points of burst of the shell.

Phosgene clouds were sometimes estimated by the colour change of detector papers exposed on posts.

Bombs dropped from aircraft were assessed by a circular layout similar to that for static trials, and, it was stated, the pilots were very successful in aiming the bombs at the centre of the circle from a height of 2000 metres. Later the best pilots were lost in a flying accident and since then the aiming was not so successful. Attempts had been made to sample multiple shoots of nebelwerfe with lines of bubblers, but these were unsuccessful owing to scatter. In spray trials the bubblers were arranged in lines about 10 m. long about half way along the spraying run; no attempt was made to assess the whole of the emission.

Animals were used extensively during trials, and were stationed at, or alternatively with chemical sampling positions. With newer agents the animal results were weighted higher than the chemical, and not until correlation between animal results and chemical estimation had been thoroughly established were animals dispensed with. The physiological aspect of field trials is dealt with more fully in Appendix III.

Particulate toxic smokes, such as DM, were sampled by drawing air, by means of an injector through a glass funnel containing a filter cartridge. (See paragraph 7 of this Appendix). The kinegraph was also used for obtaining a continuous record of a particulate cloud, the trace on the film being measured by a photometer.

Ground contamination was measured by earth sampling, and by dabbing the ground with cloth stretched across a mallett, the transferred agent being estimated physiologically or chemically. Contaminated areas were frequently delineated by the use of "Spürhunde" or detection dogs. These animals, which had been given a long training, were able to detect the boundaries of a contaminated area with precision and were especially valuable for studying the rate of shrinkage of a contaminated area with time. Use was also made of the vegetation in demarcating contaminated areas. A species of grass, growing only on the Heide was very sensitive to mustard gas, turning red in its presence, and the young cones of the pine trees were found to give a semi-quantitative indication by the amount of droop exhibited.

Volunteer human observers were used during field trials. This aspect is dealt with in Appendix III.

Smoke was not scientifically assessed in the field. No expenditure figures for smoke munitions were requested by the army, who

eried on seeing smoke generators at demonstrations, and judging the number required during an operation according to the local circumstances. Experimental stores were judged by a rough comparison of the amount of smoke by rule of thumb. Corrections for meteorological conditions were not applied although it was known that smoke was best with a normal speed of 2-6 m./sec., in the morning or evening, under cloudy skies, with temperatures under 18°C and high relative humidity. These facts were known as the result of experience over a length of time, and not as the result of systematic observations. The use of the factor R was known from captured documents, but was not applied (see also paragraph 9 of this Appendix).

Trials of anti tank weapons were carried out with tanks from which the engine had been removed and a fan installed to simulate the ordinary rate of ventilation. Glass bottles containing hydrocyanic acid were estimated by putting animals in the drivers', commanders' and gunners' positions. The effect of harassing agents on tanks was also estimated by using an engineless tank, the observers running out from shelter immediately after firing and putting their heads into the back of the tank through opened doors. No details of trials with moving tanks could be obtained and these were thought to be rarely attempted.

Lachrymators and sternutators were mainly assessed in the field by using human volunteer observers, but no objective methods of assessing the effects were used, reliance being placed upon the description of their symptoms given by the observers.

Aircraft spray was assessed chemically by bubblers, by visual, and sometimes chemical, assessment of contamination density, by exposing shaved animals (with or without clothing) and by exposing the left sleeve of clothing which was subsequently worn by men for several hours. Men, as far as can be ascertained, had never been exposed to direct vesicant spray. Non-physiological assessment was by weight only, this sometimes being done by matching the contamination on dyed jump cards or paper strips against a book containing a number of typical patterns. Drop sizes and drop size distribution have never been estimated.

The aircraft used for spray and bomb trials was mainly the Ju 88, although the Ju 87 was formerly used and the Me 110, F.W.190 H.O.126, D.O.217 and 218 were also sometimes used. Most bomb dropping trials were done at a height of about 500 metres at a speed of about 360 km/hr., and spray trials at heights of 10-20 metres and 360 km/hr. Other

speeds and heights were used, but there appeared to have been no systematic study of the effect of height and speed on performance.

The soil at Raubkammer is very sandy and it was recognised that the results obtained might for this reason be unrepresentative. Attempts were made to establish the principle that all munitions should be tried out on a number of different soils, but without success, as O.K.W. refused permission to arrange trials elsewhere. It might be remarked here that no trial involving C.W. materials could be done outside the limits of Raubkammer without the express permission of O.K.W. and this was difficult to obtain. A specific request to carry out trials in mountainous country in Styria was refused, but a trial ground in Galicia was authorised (see below).

Substitutes were sometimes used for thickened mustard gas in order to avoid incommoding the Nebeltruppe, who used the Raubkammer ranges for training. A suspension of magnesium oxide and carbonate in water and glycerine was used for this purpose in some experiments, and in others, oil or grease.

It was intended to test aircraft spray from high altitudes but the range at Raubkammer was considered to be too small for this purpose. An area of 320 sq. km. at Ravaruska in Galicia was selected as a trial ground, but owing to military events, was never used. High spray trials had therefore not been attempted.

11. Analytical Methods

The analytical methods used were, for all the orthodox gases, quite normal, and there was no novel feature worthy of note. On the whole the methods appeared somewhat insensitive and would not have been capable of estimating small concentrations of gases. The following are some of the more important field analytical methods.

Mustard gas. Absorption Apparatus - 1 or 2 wash bottles connected in series. Filling - 10 cc. N/1 KMnO_4 , 10 cc. Glacial Acetic Acid, 60 cc. Water. Should the mustard gas concentration be too high the quantity of permanganate solution can be increased. Sampling rate - About 50 litres per minute. The contents of the wash bottle are allowed to stand for $\frac{1}{2}$ hour and then reduced with per hydrol, added drop by drop, and extracted with benzene on a sand bath for $1\frac{1}{2}$ hours. The benzene extract is treated with 10 cc. of 30 per cent NaOH and 40 cc. of water and boiled. After the benzene has been evaporated, if the solution should be brown coloured, it is again treated, drop by drop, with per hydrol.

It is then boiled for 15 minutes, cooled, acidified with 10 cc. of 10 N sulphuric acid using methyl red as indicator, diluted with water and the chloride titrated potentiometrically with 1/10 N silver nitrate.

For estimating mustard gas on the ground, a 10 cm. square is carefully skimmed off and allowed to stand over-night with an KMnO_4 /acetic acid mixture as above. Should the whole of the permanganate be consumed a further quantity should be added. After 24 hours the mixture is filtered off through a suction filter and the filtrate cautiously treated with per hydrol until decolorised. An aliquot part is taken off and treated as above.

This method of estimation is based on the fact that mustard gas sulphone is extracted by the benzene.

HN-3 Absorption Apparatus - 1 or 2 wash bottles in series. Filling - 80-100 cc. of Sulphuric-Alcohol Solution (10 cc. Sulphuric Acid S.G. 1.84 + 1 litre of Alcohol). Sampling rate - About 40 litres per minute. The liquid is washed into a 200 cc. measuring flask and filled up to the mark. 100 cc. are put into a beaker and the inorganic chloride titrated with 1/10 N silver nitrate. The remaining 100 cc. is treated with 5 cc. of 30% caustic soda solution and boiled on a water bath for $1\frac{1}{2}$ hours. It is then treated with 10 cc. of 10 N sulphuric acid and after cooling the total chlorine estimated with 1/10 N silver nitrate.

Cyanogen Chloride. Absorption Apparatus - 1 or 2 wash bottles filled with 80 cc. of water and 5 cc. of 30% caustic soda. Sampling rate - About 40 litres per minute. The solution is acidified with 10 cc. of 10 N sulphuric acid and the chloride estimated by means of 1/10 N silver nitrate. The CN is oxidised to cyanate and does not react with the silver nitrate.

Cyanogen Chloride and Hydrogen Cyanide in admixture. Absorption Apparatus - 1 or 2 wash bottles. Filling - 80 cc. water, and 5 cc. 30% caustic soda. The mixture is transferred to a measuring flask and half of it treated with 5 cc. of 10 N sulphuric acid and the HCN cautiously boiled off. After cooling, the residual liquid is diluted with water and the chloride estimated with 1/10 normal silver nitrate. The second half of the solution is treated with an exactly measured quantity of 1/10 N silver nitrate in excess. It is then treated with 5 cc. of 10 N sulphuric acid and the white chloride precipitate filtered off. The excess of silver nitrate is back-titrated with 1/10 normal potassium chloride thus giving the total chloride and cyanide in the mixture.

HCN.

Method A. 1 or 2 bubblers containing 90 cc. water and 5 cc. 30% caustic soda. Sampling rate - About 40 litres per minute. The solution is treated with an exactly measured quantity of 1/10 N silver nitrate (a slight excess) and then acidified with 10 N sulphuric acid (until the disappearance of the brown precipitate) and filtered. The excess of silver nitrate in the filtrate is back-titrated with 1/10 N potassium chloride.

Method B. 2 wash bottles containing (1) 20 - 50 cc. 1/10 N silver nitrate made up with sufficient water to cover the diaphragm, (2) 10 - 30 cc. 1/10 N silver nitrate and filled up with water. The solution is filtered and the excess of silver nitrate titrated against 1/10 normal potassium chloride. This method is suitable for small concentrations. With larger concentrations there is a risk that the quantity of silver nitrate is insufficient. If there is a suspicion of this, measured additions of silver nitrate solution can be cautiously made until no more precipitate forms.

Arsine. Absorption Apparatus - 1 or 2 wash bottles containing an exactly measured quantity of 1/10 N silver nitrate. Sampling rate - 15 litres per minute. The precipitate is filtered off and the excess silver nitrate in the filtrate titrated against 1/10 N potassium chloride.

Arsine (2nd Method). Absorption Apparatus - 1 or 2 wash bottles containing 10-20 ccs. of normal silver nitrate solution made up to the total volume of 90 cc. with water. Sampling rate - 30 litres per minute. The black precipitate formed in the wash bottle is treated with 5 cc. concentrated nitric acid and 5 cc. of perhydrol and dissolved by warming on the water bath. After standing 1 or 2 hours the solution is transferred to a 500 cc. beaker and concentrated down to about 150 - 200 cc. The gently boiling clear solution is treated with solid sodium bicarbonate until a slight turbidity appears. Immediately the solution is treated with 2 cc. of 30% sulphuric acid, thus obtaining a completely clear solution, which is boiled for 10 minutes to drive off the carbon dioxide. To the hot clear solution is added 2 grams of sodium acetate dissolved in 4 cc. of water causing precipitation of silver arsenate. After cooling (for some hours in running water) the solution is filtered and the precipitate washed with 100 cc. sodium acetate (2%). The precipitate is dissolved in 50 cc. hot sulphuric acid (as above) and washed through with 100 cc. hot water. The silver combined with arsenic acid is titrated with 1/10 normal potassium chloride solution.

$$1 \text{ cc. } 1/10 \text{ KCl} \quad \equiv \quad 2.597 \text{ mg. AsH}_3$$

Total Arsenic (Organic and Inorganic) (Method for all blue cross substances). Absorption Apparatus - Glass funnel with perforated glass diaphragm and 1 or 2 filter pads. Sampling rate - About 20-40 litres per minute according to concentration. An oxidation mixture of 1 volume sulphuric acid and 2 volumes of perhydrol is prepared in a beaker and poured over the filters which have been placed in a round bottomed flask. Glass beads are put into the flask to prevent bumping of the liquid. It is then heated very cautiously to avoid frothing over of the liquid. If the reaction is violent cooling is necessary. When the main reaction is over the liquid is more strongly heated. Should the solution show a brown colour, further perhydrol should be added until it remains odourless on further boiling. The solution is then heated until it fumes and after cooling a small pinch of hydrazine sulphate added. It is then boiled for $\frac{1}{2}$ hour to destroy the excess hydrazine sulphate and cooled. It is then diluted with water and after adding 500 mg. potassium bromide titrated potentiometrically with $\frac{1}{10}$ normal potassium bromate.

Blue Cross Substances on the Basis of the Organic Arsenic Method.
Absorption Apparatus - Glass funnel with perforated glass diaphragm and one or two filter-paper pads. Sampling rate - 20-40 litres per minute according to concentration. The filter paper is extracted by means of 60 cc. of hot alcohol used in small portions of about 10 cc. each. After extracting, the extract is allowed to cool well and treated with 10 cc. of benzene, 4 cc. of water and 1 gram of sodium chloride. Titration is with $\frac{1}{10}$ or $\frac{1}{100}$ N Iodine.

The estimation of Clark 2 is somewhat different. The extract (obtained as above) is treated with 8 cc. glacial acetic acid and 40 cc. of water and boiled for 5 minutes, to drive off the HCN. Then, after cooling, 10 cc. of Benzol and 1 gram of sodium chloride are added and the solution titrated as before.

Thickened Mustard gas. About 500 mg. of thickened mustard gas is weighed into a 100 cc. measuring flask, dissolved in benzene, and made up to the mark. For the estimation 10 cc. portions are taken out with a pipette.

Apparatus - 100 cc. erlenmeyer flask (with ground stopper). 20 cc. $\frac{X}{1}$ potassium permanganate solution, 10 cc. of glacial acetic acid, 5 cc. of water. The 10 cc. of mustard gas solution are added to the above reagents and allowed to stand for $\frac{1}{2}$ hour. Perhydrol is added, drop by drop, until the colour has disappeared and the solution then extracted for $1\frac{1}{2}$ hours with benzene. The benzene extract is

treated, after cooling, with 40 cc. of water and 10 cc. caustic soda (30 per cent) and the benzene driven off over a hot plate. Should the extract become dark in colour, more perhydrol should be added. Should the colour still not disappear it must be oxidised with potassium permanganate. When the solution is colorless to pale yellow, it is heated for a short time to destroy residual perhydrol and after cooling and acidifying, transferred to a beaker and titrated with 1/10 silver nitrate.

HT. (a) Determination of H-content. Weigh out about 80 mg. of HT in a weighing bottle and break into a flask containing the following solution:-

20 cc. of X/1 KMnO_4
10 cc. of Sulphuric Acid 10 N.
5 cc. of Water.

Allow to react in the cold for $\frac{1}{2}$ hour, then treat with 10 cc. of silver nitrate 1/10 N and leave in the cold for a further 15 minutes. Then add 80 cc. X/1 potassium permanganate, 10 cc. water and heat on the water bath for 4 hours. After cooling, decolourise with perhydrol and extract with benzene for $1\frac{1}{2}$ hours. Then add 40 cc. of water and 10 cc. of caustic soda (30 per cent) and heat on a hot-plate until the benzene is driven off. If the solution is a dark colour it must be decolourised with perhydrol and boiled for 10 minutes to destroy excess of the latter. After cooling, acidifying, and diluting, it is titrated with 1/10 N silver nitrate.

(b) Determination of Total H (i.e. H + T). 60 - 70 mg. of HT are weighed out in a weighing bottle, and the latter broken into a 100 cc. measuring cylinder containing 10 cc. of 10 N sulphuric acid, 20 cc. of glacial acetic acid and 5 cc. of perhydrol.
(N.B. in preparing this solution the last two must be added with cooling). After standing for $\frac{1}{2}$ hour in the cold, the solution is made up to 100 cc. with water. 50 cc. are pipetted out and extracted with benzene for an hour and a half. The rest of the process is similar to that in (a) above.

(c) To estimate HT in the field the following method is used. Absorption Apparatus - 1 or 2 wash bottles containing 10 cc. X/1 KMnO_4 , 10 cc. glacial acetic acid and 60 cc. water. Sampling Rate - 40 litres per minute. The estimation is similar to that for mustard, except that a 'calibration' determination must be carried out to determine how many mg. of the material correspond to 1 cc. of N/10 AgNO_3 .

This is done as follows:-

50-80 mg. mustard are weighed into a weighing bottle and then placed in a erlenmeyer flask with about 120 cc. of alcohol and 5 cc. caustic soda (30% solution). After about one hour 60 cc. of water are added and the solution boiled on the water bath and after cooling acidified with 10 N sulphuric acid and titrated with 1/10 N silver nitrate.

Mustard gas by the Total Halogen Method. Absorption Apparatus - 1 or 2 wash bottles. Filling - 80-90 cc. of alcohol and 5 cc. 30% caustic soda. Sampling Rate - About 40 litres per minute. The liquid in the flask is treated with about 60 cc. of water and heated for one hour on the water bath. It is then acidified with 10 cc. of 10 N sulphuric acid using methyl red as indicator and titrated ~~potentiometrically~~ potentiometrically with 1/10 N silver nitrate.

Tabun by determination of phosphorus. 1 - 2 wash bottles. Contents - 30 cc. N/10 KMnO_4 , 1 cc. concentrated sulphuric acid 1.84 filled with water until the glass packing is just covered. Sampling Rate about 40 litres - min.. After exposure to the gas, each bottle has 5 cc. concentrated nitric acid added and is placed on the boiling water-bath for 3 hours, reduced with H_2O_2 until decolourised, emptied into a beaker and evaporated to dryness on a water-bath or sand-bath. Then 25 cc. water, 5 cc. HNO_3 and 15 cc. Ammonium nitrate solution are added, the mixture is heated and precipitated with 25 cc. ammonium molybdate (175 g. in 1 litre of water with 1 litre 50 per cent HNO_3 added). After 3 hours it is filtered through a filter the precipitate is washed with 5 per cent KNO_3 and dissolved in an exactly measured quantity of N/10 NaOH . The excess of the alkali used for dissolving it is titrated back with N/10 sulphuric acid using Phenolphthalein as indicator. The difference gives the amount of alkali used.

1 cc. alkali = 0.704 mg. Tabun.

Tabun by CN determination. 2 wash bottles in series. Filling Toluol 80-120 cc. according to time of exposure and rate of flow. After the absorption air is drawn through the bottles by means of the filter pump to remove free HCN. Then an aliquot part (50 cc.) is shaken for 5 minutes with 80 cc. NaOH 1/100 N, and after the two layers have settled the aqueous phase is poured through a filter and 50 cc. of it are treated with 5 cc. NaHCO_3 (2 per cent) and 5 cc. KI solution (10 per cent) and titrated with 1/100 normal iodine after addition of starch.

Note. The amount of toluol is determined by weight. This is done by weighing the dried bottles on a pointer-balance before and after filling. Since there is a loss of toluol during the absorption, it is sufficient if the bottles are weighed after the absorption. The difference between the empty weight and the weight after absorption gives the weight of the filling. Alternatively the toluol filling after the absorption may be poured into a measuring cylinder, filled up to the mark and aliquot parts taken. The method can be left to the worker.

Sarin or Soman by determination of phosphorus. 1 - 2 wash bottles in series. Filling - 80 cc. N/50 NaOH (packing covered). Sampling Rate about 40 l. per minute. After the absorption the liquid is poured into a beaker and a small excess of dilute sulphuric acid is added (indicator methyl red) and it is evaporated nearly to dryness on the water bath or sand bath. The material is then washed, using a small quantity of water, into a silver crucible containing 5 cc. of 20 per cent sodium carbonate solution, evaporated to dryness and heated in a muffle furnace (700°). Then it is washed into a beaker with water, acidified with 5 cc. HNO₃ and the phosphorus precipitation carried out as for Tabun.

	1 cc.	1/10 NaOH	=	0.609 mg. Sarin.
for Soman	1 cc.	1/10 NaOH	=	0.792 mg. Soman.

Sarin by HF Determination. The method is the same as the CN determination for estimating Tabun, with the difference that 50 cc. of the toluol absorbent are shaken for 10 minutes with exactly 80 cc. of 1/100 NaOH. The two phases are separated as in the Tabun estimation and the excess of unused alkali in 50 cc. of the filtrate are titrated back with N/20 HCl. The Taschiro indicator is used. According to the literature this is a mixture of Methyl red and Methylene blue.

12. Interpretation of results of field trials.

In the absence of any complete field trial reports (Note - some microfilms which have been sent to U.K. for reading appear to contain a few field trial reports. These will be examined and reported on separately) it is not possible to obtain a clear idea of the method of interpreting the data obtained during field trials. From questioning however the following facts appear to be established.

- (a) Animal results were regarded as more reliable than chemical analysis results and were given preference in case of conflict.

- (b) Meteorological conditions (not including the factor R) were recorded for each trial but were not introduced into the computation although they were made use of in a rough and ready way. Their use was little more than to explain, and provide a reason for rejecting, anomalous results.
- (c) Dosage expressed in terms of concentration x time, although recognised for expressing physiological effect was not used in the interpretation of field trials. Instead the results were expressed in terms of "lethal areas" and "total effective areas". The former was the area over which the death of all animals was obtained, the latter over which illness or death of animals occurred.
- (d) There was little attempt to study methods of interpreting and expressing efficiency of weapons. This was possibly due to the fact that there was no one section whose business it was to study all aspects of field trials.

13. Results of field trials.

As remarked above, no complete field trial report has yet been examined. Tabular summaries of field trials, prepared by the head of Gruppe VII b for the purpose mainly of displaying physiological results, have however been seen. These, because of their physiological bias, have been dealt with in detail in Appendix III, but where relevant some of the material has been used in other Appendices.

14. Summary and appreciation of Field Trials Organisation

The range at Raubkammer is of ample size with substantial safety margins around the main clear experimental area. It is, moreover, flat so that air flow is regular and unimpeded. Consequently trials could be done with the wind in any direction and only very bad weather caused interruption of programmes. This happy feature of the range enabled fixed points to be selected at which the major trials were carried out and these points were fitted up with permanent layouts of wiring and sampling and control points. By this means trials were so simplified that in most cases no detailed written programme was necessary and for this reason, and because of the ample laboratory space and the lavish stock of sampling apparatus a mass

of work could be carried out at high speed. Further a number of trials could often be done on the same day under similar meteorological conditions, enabling valid comparisons to be made without the introduction of corrections for atmospheric factors.

Several features of the range work at Raubkammer appear, as far as can be judged before they have been subjected to test, worthy of commendation.

The Vauzet Turm appears to be a valuable piece of equipment for the study of the ground burst type of shell and the installation of a similar piece of equipment merits serious consideration by Allied chemical warfare research installations. The system of using fixed sampling centres provided with rails with which to run trolleys containing sampling apparatus is also commendable, although of course only ranges where ample margins exist in all directions could accommodate them. Another useful feature is the series of gas-tight concrete observation towers from which shoots can be controlled from close to the point-of-aim without harm from even direct hits by gas shell. Again only ranges large enough to carry out shoots at a fixed point with any wind direction could economically instal such equipment.

On the other hand it is difficult to see that the Messhaus, despite the fact that another and larger one was being prepared, fulfilled a purpose of value commensurate with the expense of building and maintaining it. It served a purpose in giving a rough indication of the degree to which a chemical agent was decomposed by bursting, and was, it was ascertained, used as an intermediate stage between explosion tests in small containers at Spandau, and trials in the field at the Vauzet Turm. This indication could only have been very approximate and in our opinion little would have been lost by going straight from the Spandau bursting trials to the Vauzet Turm trials.

Referring back to the facility with which trials could be performed at Raubkammer, it seems to us that the emphasis on the reduction of field trials to a routine matter, and the failure to appoint a section whose sole function was to design field trials (as distinct from the development of field analytical methods) had the unfortunate effect of eliminating imagination in framing them and so prevented, to some extent, the introduction of realism into the interpretation of results. We think that this had a fundamental effect on the German outlook on chemical warfare and, for example, was at least in part responsible for their overlooking until recently the study of micro-meteorology, their comparative neglect of vapour effect from mustard contamination, and their belief in the offensive properties of arsenicals.

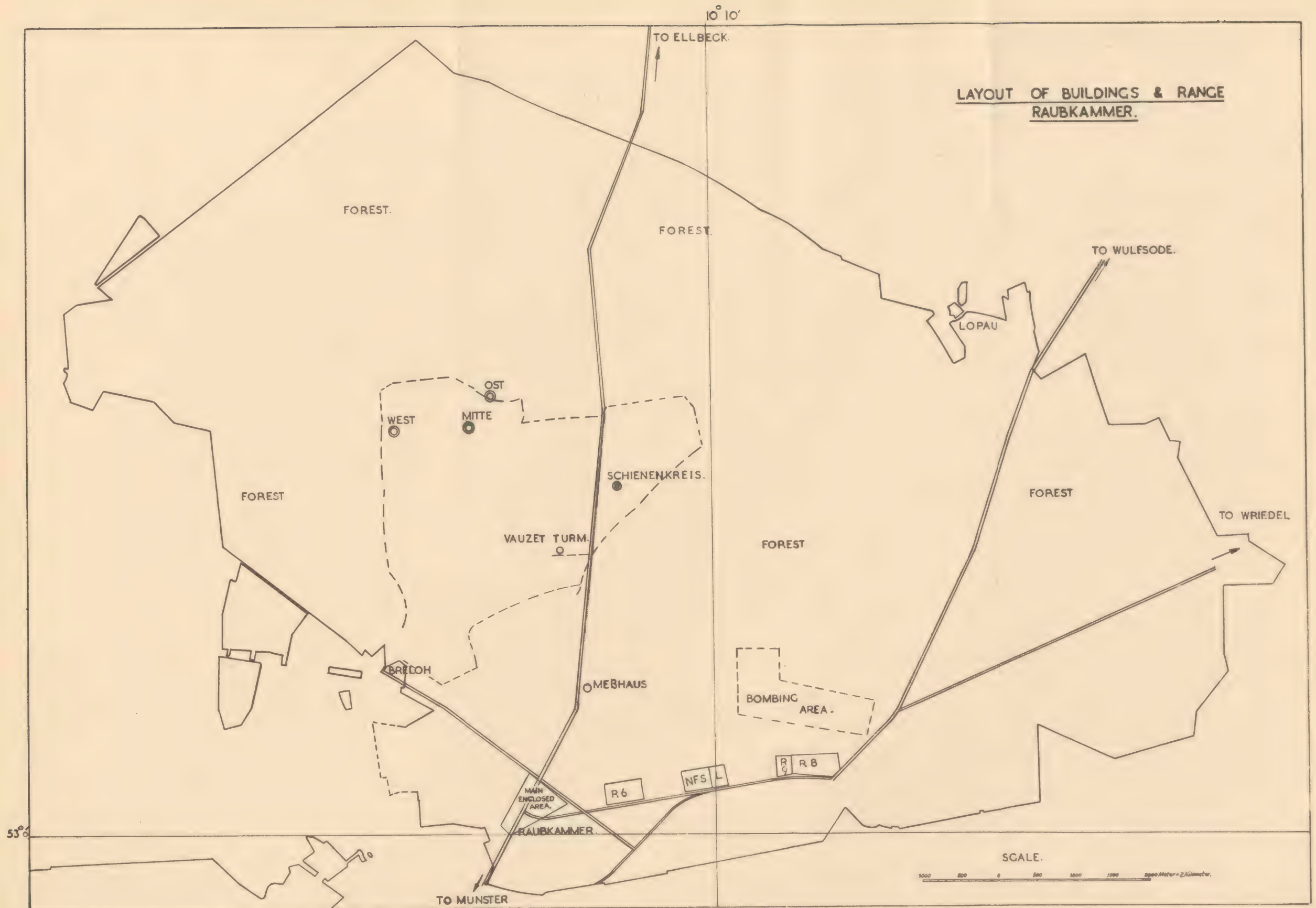
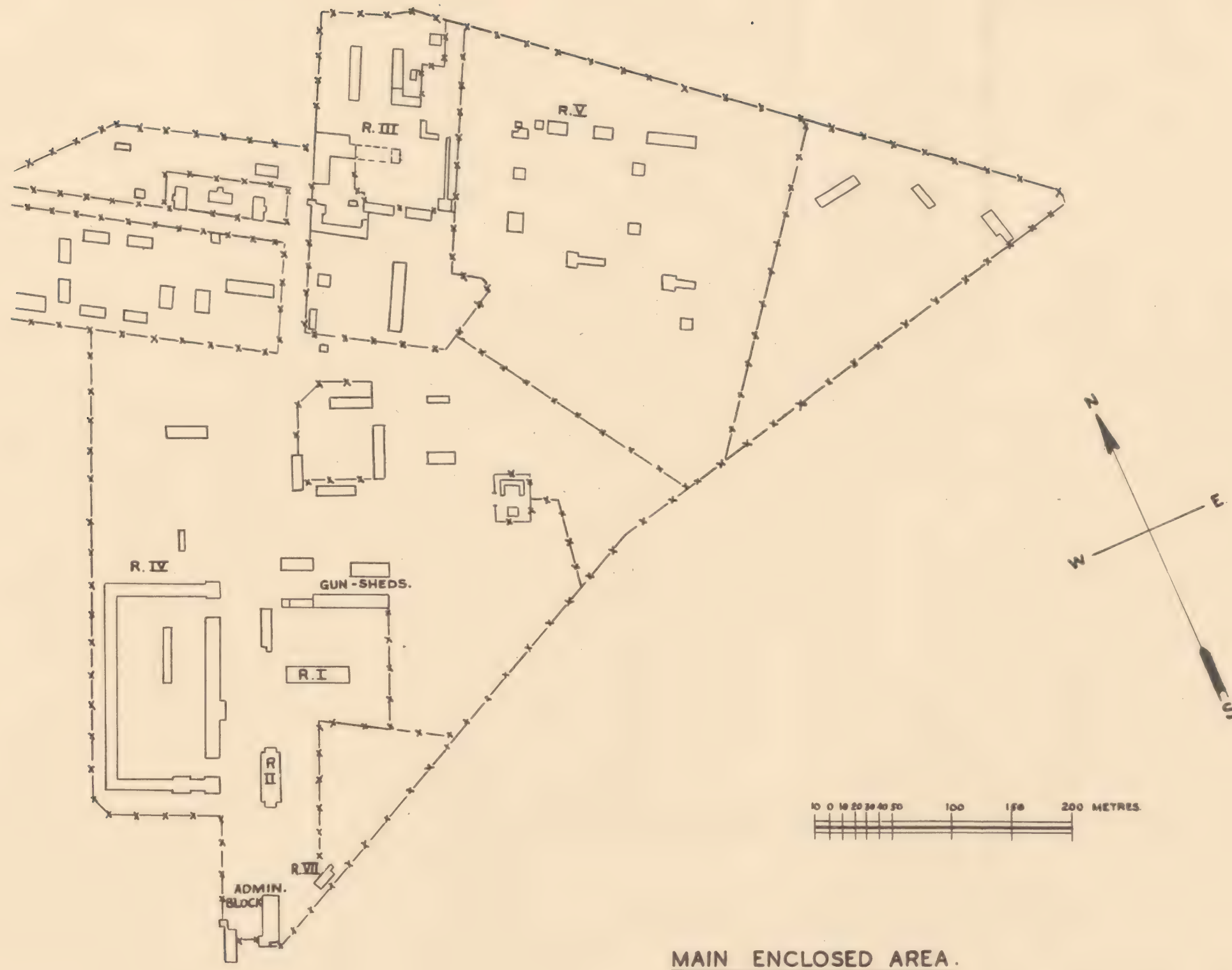


FIG. I.



MAIN ENCLOSED AREA.

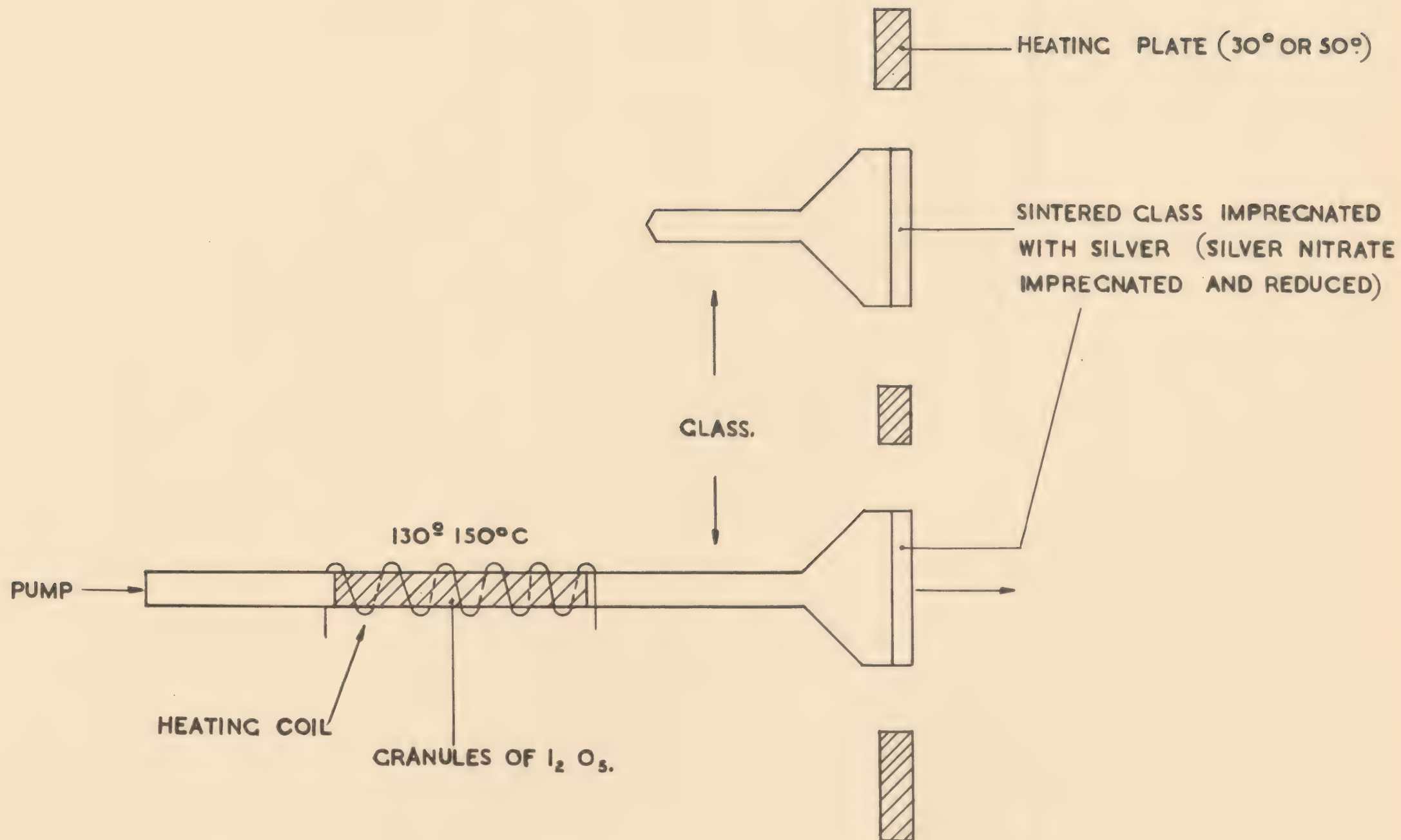


FIG. III.

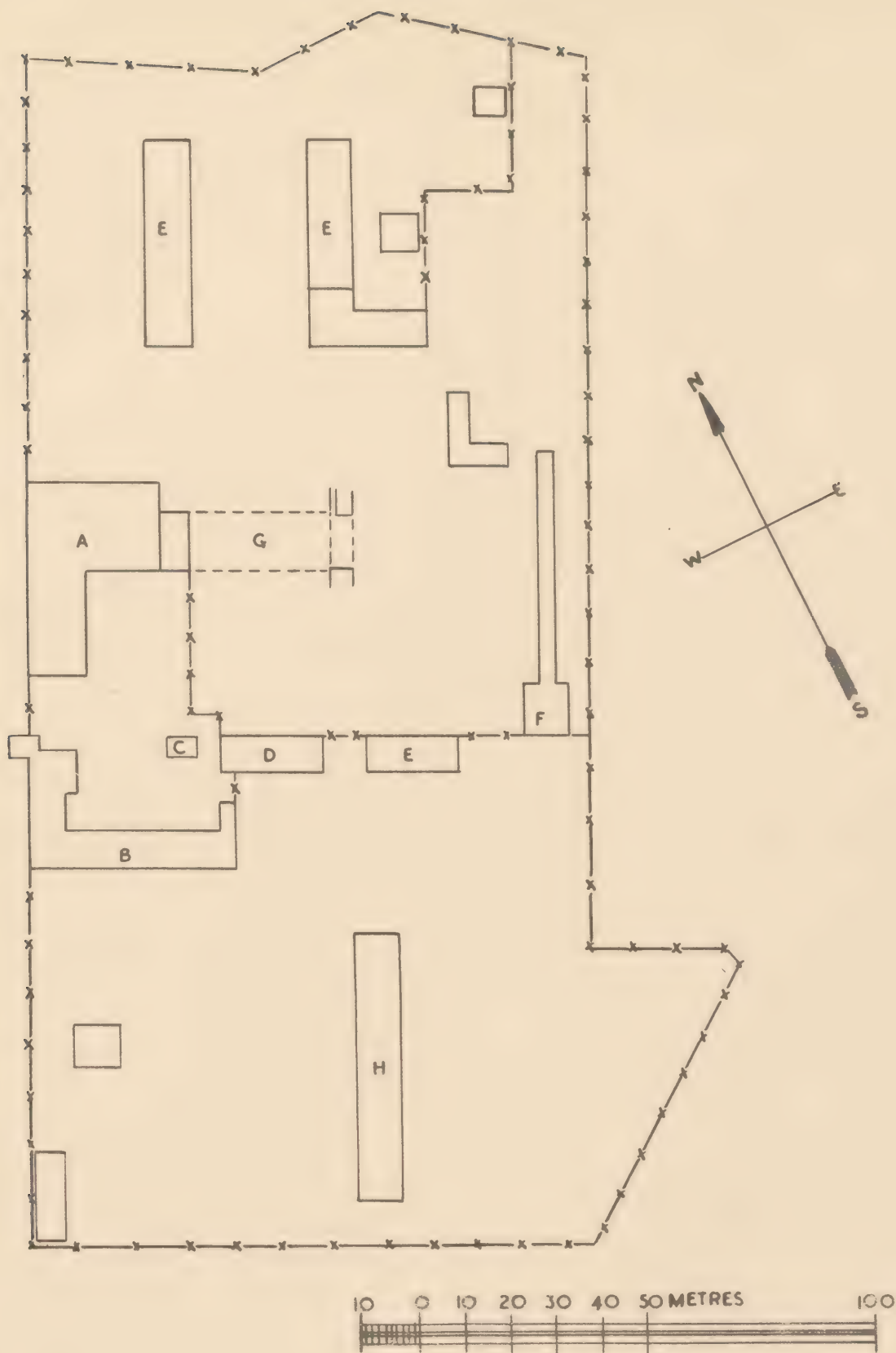


FIG. IV.

LAY-OUT OF R III.

Investigation of Chemical Warfare Installations
in the Munsterlager Area, including Raubkammer

APPENDIX II - Defensive Aspects

1. Introduction.
2. Respirators.
3. Collective Protection.
4. Protective Clothing.
5. Detection.
6. Decontamination.
7. Description of RIII, Raubkammer.

APPENDIX II

Defensive Aspects

1. Introduction

The defensive aspects of German Chemical Warfare Research and Development came mainly under the control of Groups II, III, IV and XIII of Wa. Prüf 9. Group II was responsible for the individual protection of men and animals by the way of provision of respirators and protective clothing, including gas planes. Group III covered collective protection, detection and decontamination both of personnel and of equipment and materials. Group IV dealt with vehicles and ploughs for decontamination and Group XIII covered the wider aspects of animal defence besides veterinary research.

At Spandau, II L carried out the research and development for Group II, III L for Group III, IV L for Group IV and IIcL for Group XIII. There was not quite such an exact correspondence of function at Raubkammer. All the field trials of defensive equipment, and of detection and decontamination methods were carried out by R.III. Decontamination vehicles were maintained by R.IV, the transport section. A new section, R.IX, for veterinary research was being set up and was almost completed. This would have dealt with animal defence.

The information contained in this Appendix was gained by interrogation of staff from Wa.Prüf 9, Spandau and Raubkammer and by inspection of buildings and equipment at Raubkammer. Fuller technical details will be available when the documents and equipment being sent back to U.K. from Raubkammer have been examined.

The following were interrogated :-

Oberst Hirsch	Chief of Wa.Prüf 9.
Dr. Schmidt	Chief of Group II
Dr. Gustav Schömann	II L
Herr Erich Bobertag	Chemietechnischer, II L
Herr Paul Fliescher	Laborant, II L
Dr. Guggolz	III b
Herr Albert Dankert	Chemietechnischer, III a L
Dr. Rudolf Schönmann	III b L
Herr Hans Brinkhoff	Chemie Ingenieur III b L
Herr Gunther Rode	Laborant III b L
Herr Georg Waldner	Chemietechnischer III b L
Dr. Herbert Meiner	III c L
Herr Hans Gunzel	Chemietechnischer III c L
Dr. Hermann Specht	III c L
Dr. Kuhk	Head of R III.

2. Respirators

(A) Charcoal

Five different types had been used in recent manufacture of containers. These comprise :-

Zsa:	Peat charcoal, zinc chloride activated, impregnated with copper and silver. Zsap when pyridine impregnated.
Wsa:	Beech wood charcoal, steam activated, impregnated with copper and silver. Wsap when pyridine impregnated.
Ska:	Peat charcoal, activated with potassium sulphide, impregnated with copper and silver. Skap when pyridine impregnated.
Ra:	Beech wood charcoal, activated with potassium sulphocyanide, impregnated with copper and silver. Rap when pyridine impregnated.
Front layer charcoal: (Vorschicht Kohle)	A low grade wood charcoal, zinc chloride activated. Not otherwise impregnated.

Sources of manufacture of charcoal

Zsa:	Harz-Weser A.G., Langelsheim at Harz, 8 Km. W. of Goslar.
Wsa:	Mostly at Deutsche Activ Kohle Ges., Premnitz, Ratherow (in Russian zone). Smaller production at Kaig, Brelon-Wald (S. of Fodeborn).
Ska:	Premnitz.
Ra:	Ernst Beudler (Dr. Hans Walter), Lahr-Dillingen, Baden, Nr. Strasburg.
Vorschicht Kohle:	Norit, Zaandin, Amsterdam and Deutsche Activ Kohle Ges., Leverkusen (I.G.) Dr. Neimann knows process.

Brief description of manufacturing processes

Zsa. Peat is milled to form a flour, mixed with zinc

chloride solution in a kneading machine. The originally brown mixture turns black and forms a crumbly mass, which is then extruded in the form of strings 2 mm. diameter. These are cut or, more recently, broken up by folding, put in a furnace and activated at 950°C. During activation the charcoal is passed by a continuous feed through a rotating cylinder furnace and falls out at the other end into a drum which is kept fairly air-tight to prevent inflammation. After cooling the charcoal is put into acid proof containers and immersed in a water bath. Then it is successively washed in HCl, water, K₂CO₃ and CuSO₄. It is then washed again with water, filtered, treated with steam at 900-950°C. in a rotating drum furnace. After cooling it is graded and selected sizes are sprayed with silver nitrate. It is then filled into drums or sprayed with 2% pyridine before packing. The water content is 8-10%; copper 0.8-1%, silver 0.3%.

Wsa.

Beech wood is ground to a fine powder and mixed with tar from the distillation of the same material. CuSO₄ and K₂CO₃ are added either in solid form or in solution according to the factory. The mixture is extruded and dried at 300°C. in absence of air in order to form a "coke". It is then put in a drum furnace and activated at 900-950°C. with steam. After cooling, the grains are graded and then impregnated directly with silver (and pyridine). Some firms add 2 per cent alkali to increase the speed of activation, but this has to be washed out at the end of the process otherwise the chloropicrin absorption is spoiled.

Ska.

This is made from peat as for Zsa; it is kneaded with K₂S solution, mixed, extruded, and activated at 900-1000°C. After washing it is impregnated with CuSO₄ and K₂CO₃, then washed again and dried. Grading is then done and the selected size ranges are impregnated with silver (and pyridine).

Ra.

Made from Beech wood which is pulverized and mixed with Rhodan (potassium sulphocyanide), dried and activated in a drum furnace at 900°C. It is then washed, made alkaline with K₂CO₃ and impregnated with CuSO₄. After washing again and drying, the charcoal is graded and impregnated with silver (and pyridine).

Vor-
schicht
Kohle.

Made from wood by a straight forward zinc chloride activation process and not impregnated. It contains 20-30 per cent Zn as basic zinc carbonate.

Container Fillings

In the Fe37 (R) and Fe41, the first layer after the particulate filter was Zsa, followed by Wsa. The Fe42 had an additional front layer of Vorschicht Kohle. Zsa is the best charcoal for speed of absorption at high concentrations. It had a larger pore structure than Wsa as determined by adsorption experiments. Examination by the electron microscope had failed to reveal pore structure, but it was possible to distinguish between various kinds of charcoal.

If there were a shortage of Zsa, then Wsa, Ska or Ra might be used in its place. The reason for the two layers in the Fe41 and the three in the Fe42 is an economic one since Wsa was in short supply owing to requirements for the artificial wool industry.

Gas Tests on Containers

The factories assembling containers made tests only against chloropicrin at a concentration of 40 g/m^3 and flow rate of 20 l/min. Minimum service time was 65 min. This was a test merely of correctness of packing.

Special tests were made against concentrations of various gases, as under. Flow rate was usually 30 l/min. but sometimes it was increased to 60 or 100 l/min.

CG	5, 11, 100, 250 g/m^3	
AC	0.5, 5, 10, 20 g/m^3	
CK	1.2, 2.4, 5, 12 and 24 g/m^3	
SA	0.5, 2 g/m^3	
HH ₃	0.5, 2, 10 g/m^3	} only occasionally
SH ₂	2 g/m^3	

General remarks on performance of Containers against gases and recent developments

The Fe42 Container was introduced to meet a possible Russian attack with high concentrations of HCN. Some 8 millions were made, but the opinion was expressed that it was a mistaken effort, that it was unnecessary and was too heavy for the face-piece.

Wa. Prüf. 9 were asked to consider the protection afforded by containers in the event of an allied gas attack from the air. An experiment was staged in which twelve 250 kg. bombs filled with phosgene were arranged in two rows of six with 5 metres distance between adjacent bombs and burst simultaneously. At 15 metres the peak concentration was 300 g/m^3 in a wind speed 3-4 m/sec. Containers exposed at this distance were unbroken and it was therefore considered that their performance would be satisfactory against any likely allied effort. The containers tested were :- Fe41, Fe42, Russian M.T.4 and a newer one (type unknown), British E Mk.VI and light L.2, American M.10 and M.11. Air was drawn through continuously at the rate of 30 l/min.

The Fe42 gave a service time of 80-120 minutes against 1.2 g/m^3 of HCN, as compared with U.S. assault container, 200-220 minutes, U.S. lightweight container 230-240 minutes and British lightweight, 15-20 minutes. The Germans had tried experimentally a copper chromate impregnated charcoal in their Fe41 and obtained a service time of 160-200 minutes. They believed the U.S. assault container was made up from copper chromate charcoal but were not certain. They considered the U.S. assault container now to be the best in the world.

"Pyridine" was adopted in default of adequate supplies of urotropine which they considered much better. The bases actually used were the residues obtained in the rectification of pyridine; they did not consist simply of methyl pyridine, (though this term was used for convenience for describing the agent) but must have contained a large number of higher homologues. Although pyridine itself was a better impregnant, it was required more urgently for pharmaceuticals.

Impregnation was carried out by adding the liquid bases to a rotating drum of charcoal, in excess. The increase in weight was noted, and a finished batch made up by adding enough fresh charcoal to bring the total content of bases to about 2 per cent.

There was no specification for the quality of the bases used (e.g. boiling range, effective equivalent weight) nor for the amount in the finished charcoal. The service time of the respirator against AC was the only control. No analytical procedure for the evaluation of the bases on charcoal had been devised.

The value of urotropine was discovered in 1918 at the Kaiser Wilhelm Institute. Pyridine was merely a logical development. It is possible to pour pyridine into the container after assembly, but neither this method nor vapour treatment had been applied in practice.

Other metallic impregnants had been tried, viz., Cr (see above), Mn, Vn and Fe to improve HCN absorption. Poor results had been obtained with Mn (cf. work of Bordron at Le Bouchet).

The German losses of respirators on the Russian front had been terrific. It was estimated that 6 to 7 million had been lost during the various campaigns against a total production of 15 million. They were also exercised about the turn-over of containers during conditions of actual gas warfare. It was considered that 3 changes of container per month would be required by front line troops, and 1 per month by troops in rear areas. Owing to production difficulties the actual estimate for replacements during the last year of the war was $7\frac{1}{2}$ million per annum. Supply difficulties forced a reduction of this figure to $3\frac{1}{2}$ million and later it was whittled down to $1\frac{1}{2}$ million.

To meet the difficulty of containers being discarded unnecessarily before reaching the exhaustion point, the Germans tried to develop a device to indicate when exhaustion had been reached and even offered a prize to anyone who could invent such a device, but they had no success. They then turned to methods of extending the life of the container. The following expedients were tried:-

- (i) Development of method of refilling existing containers in mobile workshops in the field. Found to be impracticable.
- (ii) Development of a new container with a clip on particulate filter and refillable charcoal component. Again not practicable.
- (iii) As for (ii), but charcoal to be issued in packets for slipping into the container. The device proved to be too heavy for the new facepiece.
- (iv) Addition of a cardboard extension piece containing charcoal to clip on to the front of the container. This worked well, but the respirator carrier was too small to take the extra component and the idea was dropped.
- (v) Regeneration of charcoal by steam. This could be done 3 or 4 times and the protection only fell to 70 per cent after the third or fourth time. The method was to pass steam through the container and then hot air until the correct moisture content was re-attained. A pamphlet on the process has been obtained.

Experiments were done on the desorption of gases from containers. Containers were subjected to PS, CG, AC and CK against 50 g/m^3 for 1 min. and then left for 3-5 min. before being tested for desorption. No trace of effluent was found. If the concentrations were greater than 100 g/m^3 , a maximum desorption concentration of 60 mg/m^3 was found in the case of PS, AC and CK. With the special front filter, noted above, there was no desorption after subjection to 300 g/m^3 for 1 min.

(B) Particulate Filters

The types of German particulate filters are too well known to require description and the history of their development is being covered in the report on Draeger-work. The only recent modification to the ring filter was the introduction of water-proofing. Owing to shortage of supplies experiments were also in hand to replace the asbestos by fine metallic particles such as aluminium, iron, and copper as suggested by Prof. Ebart of Vienna, but no success had been achieved. They had tried incorporating charcoal in the paper both in granules and in fibrous form like artificial silk and the developments appeared promising. Simplification of details of manufacture of ring filters was also being studied, but no development of an entirely new filter was being undertaken.

Testing

Tests were both subjective and nephelometric. For the subjective test, Clark I was dispersed in a concentration of about 100 mg/m^3 in a 20 m^3 chamber by means of a miniature thermal generator (Schwelkörper) which gave a cloud of fine liquid particles. Observers, at rest, breathed through containers for 20 mins. If no subjective effects were experienced the containers were considered satisfactory. The high concentration was chosen in order to maintain as high a standard as possible and to enable effects in the case of unsatisfactory containers to be obtained quickly.

The nephelometric test was similar to that used at Draeger-work and a sample of the apparatus is being sent to U.K. from there. This test consists essentially of spraying tri-cresyl phosphate, heated to 100°C . to reduce the viscosity, filtering out the larger particles and then estimating the effluent, after passage through the container, by means of a Pulfrich photometer.

A modification of the photoelectric apparatus developed by Draeger was also being tried at Spandau, but owing to lack of skilled personnel little progress had been made.

Results of test

The U.S. filter (shell type) was found to be the best since it had a low resistance combined with a very high filtering efficiency. German and Russian filters were also good. British filters in the E.VI and the Lightweight respirator were variable and a percentage failed on the breathing tests, since effects were obtained in 5-10 minutes. On the other hand, all containers were efficient against Adamsite. Since the Germans did not have sufficient supplies of Clark I and II for their incorporation in thermal generators and had to rely solely on Adamsite for this purpose, there was no possibility of penetrating filters. The theory, already well-known, was put forward that liquid particles do not clog respirators but tend to open the pores of the filter and increase penetration. Even with liquid particles, penetration of respirators would be unlikely with practicable field concentrations.

Clogging of Filters

The clogging of particulate filters received attention both from the defensive and offensive aspects. Following on the French experiments, they tried blocking filters by mixing anthracene oil with DM and DC, but found no effects. Mixtures of dyes with oils produced slight positive effects with French paper filters, but were ineffective against British and Russian filters. Dusts were found to clog filters, but they can be readily removed by tapping the container. Resins, electrified dusts, etc., were found to be of no use. Swelling agents such as potassium hydroxide or cupra~~am~~monium solution had no effect on cellulose filters when used in practical concentrations.

Intelligence reports had been received that the British and Americans were intending to use powdered glass to clog the German containers. Experiments showed that with particles of 1 micron mean diameter, 5 to 10 g/m³ was required to cause clogging in a reasonable time. As an offensive agent it was found that no physiological effect was produced in concentrations up to 10 g/m³ for relatively short exposures. Silicosis was produced in animals after several weeks exposure.

(C) Facepieces

The normal types of German facepieces have been described in previous reports on captured enemy material, and methods of manufacture are being covered in reports on firms which made respirators. Here only new features of design and development are described.

Owing to shortage of raw materials, the Germans intended making a new facepiece, the GM100, which was based on an experimental model known as the GM99. This facepiece is of textile material with a thin inner skin of rubber. It has a simplified rubber band head harness, and less elaborate eyepieces and valves than in the GM38. Samples for technical examination are being sent back to U.K.

An even simpler model, the VM44, was being made for civilian purposes and it was planned to produce the first million by the end of June. If the war had continued sufficiently long, a VM45 would have been made from paper.

A sample of the GM44 optical mask was obtained. This is based on the GM38 modified to give improved performance with optical instruments.

The facepiece used in the production plant at Raubkammer appeared to be of an industrial type which is similar to the GM38 but flimsier in construction and having the outlet valve inserted in the cheek.

(D) Expiratory and Speech Valves

The Germans experienced great difficulty in obtaining supplies of mica suitable for making expiratory valves for their service respirators. Buna rubber by itself was an unsatisfactory substitute owing to sticking. The best that could be achieved was to use Buna rubber with a facing of natural rubber. Both the mica and rubber valves were known to leak, and this was particularly noticeable in high concentrations of arsenicals, such as Clark II. Although leakage was not serious from the Physiological point of view, it was considered to be psychologically bad since the troops had implicit faith in their respirators. To meet the difficulty, a "Vor" chamber containing charcoal was devised for insertion behind the valve. This was successful, but was not put into service.

The Germans were struck by the good speech characteristics of British and U.S. respirators. They endeavoured to copy the expiratory valve in the former, but could not reproduce the membrane. Eventually the design of the valve was left unaltered, but they added a cone of Buna which was to be inserted behind the existing valve and cut to shape by the troops themselves to give the best results. Some 50 per cent improvement in speech was claimed for this method. In addition a new facepiece with a mushroom speech-expiratory valve, known as the GM43, was developed. Samples have been obtained for

full technical examination. A hundred thousand of these face-pieces was on order from Auer, but the production was curtailed by our bombing.

(E) Self-contained Breathing Sets

In addition to the standard large and small oxygen sets, two "regeneration" cartridges were found at Raubkammer, viz., the Auer Pyroxylin Patrone and Draeger Seitengerat. A few hundred of the Pyroxylin apparatus were introduced into service, but they were not found to be satisfactory and they suffered from a number of disadvantages. If the user starts to work hard directly after donning the apparatus, he finds the oxygen supply is insufficient as the full output is only reached when the apparatus has warmed up. The output of oxygen is constant and bears no relation to the work done by the wearer. Under very cold condition, generation starts with great difficulty and it was found in Norway that at $-20^{\circ}\text{C}.$, starting was very slow indeed. The exact details as to how the oxygen is generated were not obtained, but the principle of the apparatus is the release of oxygen from sodium peroxide when exposed to CO_2 . Initiation is by bursting a small CO_2 charge.

It was thought to replace the chemical action by a thermal one by use of "Nasogen", which consists of a mixture of chlorates and perchlorates with metallic oxides. The canister contains a top filter which absorbs chlorine and oxides of chlorine. The advantages of this filling are that the rate of reaction is independent of outside temperature and a sufficient quantity of oxygen of 99.7% purity is at once released. It also has the disadvantage that the supply is constant and does not vary with the amount of work being done by the wearer. Further, the container becomes so hot that it will spoil any rubber equipment with which it comes into contact. The device was not therefore introduced into service.

A special oxygen generation device had been developed in order to save weight on cylinders. "Nasogen" was contained in tin cylinders, 20 cm. diameter and 50 cm. high, which were put in an autoclave and directly attached to 60 bottles at one time which could be filled to 150 atmospheres pressure. There was also a second size of tin cylinder and autoclave. This device was also introduced in the Navy, Air Force and Army where the breathing set (Heeresatmer) was in use. It was developed at Batterfeld A.G. under Dr. Ing. Michel and was considered far more economical than oxygen cylinders.

(F) Animal Respirators

Owing to shortage of materials work on animal defence was stopped in the summer of 1944. Little that was unknown to us was therefore discovered. Respirators had been developed for horses, mules, camels and dogs (3 sizes) and protective baskets for pigeons and doves. No mask had been designed specially for reindeer in the Finnish campaign. A number of different types of animal respirator some of them novel, have been sent back to U.K. for examination.

Collective Protection

(A) Room filters

Only four sizes of collective protection units for rooms were found, viz., those of 0.6, 1.2, 2.4 and 10 m³/min. output, but actually two further sizes, 5 and 7.5 m³/min. were produced, although no examples of these were seen at Raubkammer. Each of the units has its own type of blower which can be electrically driven or, alternatively, manually operated.

The units do not embody any novel features. The latest pattern incorporates both the charcoal part and the particulate filter in the one container. Details of the methods of construction of the various sizes are dealt with in the report on Draegerwerk.

Development of improvised means for obtaining gas protection of non-permanent fortifications and civilian air raid shelters was being undertaken. The filter system consisted of a wooden box containing a layer of wood charcoal, followed by sawdust covered with a top layer of earth and sand. Ventilation was obtained by manually operated bellows constructed from wood and some flexible material such as oppanol. In one type that was seen, there were two bellows which were operated from a single pivoted beam. Similar filter units had been improvised for civilian shelters.

It was claimed that the filter would deal with persistent gases and particulates. It would be ineffective against any but very low concentrations of non-persistent gas, but protection against these could be obtained by shutting down ventilation. The duration of a non-persistent gas attack would not be so long that any ill effects would arise through temporary lack of ventilation. On the other hand, the danger from vapours from vesicants might persist for hours in which case adequate protection and ventilation could be obtained with this unit.

Testing of room filters. Filtration units incorporated a simple form of rotameter to indicate that the correct rate of flow was being maintained. In addition there were available test kits, one for each size of unit, which consisted of well made plate orifices with U-tube manometers and adapters for making connection to the unit. A sample of one of these had already been received at Porton, but others are being sent back to U.K. for examination.

No evidence of full-scale tests of the charcoal part of the unit was obtained, but it was stated that samples of the charcoal for units were subjected to a tube test.

The efficiency of the particulate filters of collective protection units was tested by exposing them to a concentration of 25 mg/m^3 of Clark I, observers being used to detect any penetration. The observers breathed through masks connected to the effluent of the system. The test was over a duration of 30 minutes, but the first 5 minutes were regarded as critical. The flow through the unit was checked during the test by making use of the appropriate standard plate orifice.

The Clark I smoke was generated in what is virtually a homogeneous cloud apparatus. The substance was contained in a cylindrical glass vessel with a sintered glass base placed in a cylindrical electrically heated oil bath thermostated to 160°C . Nitrogen was blown through a coil, also heated by the oil bath, and passed through the sintered glass and the Clark I. The vapour thus evolved passed over a sparking plug whilst condensing, and thus a fine cloud was produced. There was one apparatus for the $0.6 - 2.4 \text{ m}^3/\text{min}$ units and another, embodying slight modifications, for the $10 \text{ m}^3/\text{min}$ units. Examples of both have been obtained.

The concentration of Clark I was checked by taking samples on Schleicher and Schull filter discs at a rate of flow of 30 l/min .

Leakage of the system as a whole could be tested by means of a small thermal generator containing Clark II. This was similar to the "Schwelkörper" mentioned in Section 2 (above) as being used for breathing tests with respirator containers, except that it was electrically ignited and contained about twice as much material. The generator was functioned outside the inlet of the unit and any leakage was detected subjectively by observers stationed near the outlet.

(B) Collective Protection of Tanks

The Germans appreciated that tanks were vulnerable to gas attack. A demonstration was given to Gen. Guederian in which cats in Churchill, General Lee and Tiger tanks were killed by lethal gas attack, and following this the development of measures to protect tank crews was put in hand. Two methods of defence were explored:

- (i) They endeavoured to obtain individual protection by means of a piped supply of filtered air to each member of the crew. After some trials, the idea was abandoned on the grounds of restriction of movement and vulnerability of the system.
- (ii) The second method, which was the one finally adopted, was to build a gas-tight wall between the engine and the crew and to install a filtration unit for the turret and driver's compartment. The unit was designed to maintain a positive pressure of 0.2 to 0.3 cm. water gauge. It was found that this was adequate even though the firing slits were open, but the gas proofing was upset by draughts and also leaks developed in the gas-tight wall.

The blower for the unit was driven by a coupling connected to the main shaft of the engine. An over-drive device was fitted so that the blower speed would not exceed 2,300 r.p.m. The engine speed had to exceed a critical value in order to maintain an adequate supply of air.

The unit itself consisted of a cyclone pre-filter for dust connected to a rectangular box containing a pleated asbestos-wood pulp particulate filter and charcoal. The cyclone dust filter was built up from a number of small tubular cyclones apparently similar in design to the "Aerotec" adopted by U.S.A. Samples of the blower, dust filter and gas filter are being sent back from Raubkammer and a complete unit is being despatched from Draeger-werk. Actually the unit was made by Auer, but Draeger were also going into production with it. Some 500 in all had been ordered.

For sunken tank turrets, a simple form of pedal operated filtration had been developed, but a sample was not seen.

4. Protective Clothing

(A) Impervious Clothing

A large amount of protective clothing of various types was seen at Raubkammer and all the types previously known to exist in service were found, some in large quantities. Several new types were seen, but until the results of visits to the actual manufacturers have been collected it will not be possible to say if any were service designs or if they were merely models in the process of development or were specially made for the work at Raubkammer. A brief description is given here of one or two of the types not previously met.

All-rubber short pants were found which, it is learnt, were for use by observers who did not wish to don full protective clothing; in this case the pants were worn with long gum boots or thigh waders of which there were large stocks. There was also a type of small overboot consisting of a golosh in rubber with a short upper of coated fabric open at the back and having tapes to permit tying above the ankles. The coating used for the fabric was not identified, but several garments, such as aprons, were made up in this material and samples have been taken.

There was no evidence of any new developments in animal protective clothing, except for the finding of a horse cover in several pieces made up of casein/ammonia coated paper with a window for the headpiece made of cellophane.

Reports describe a number of ingenious, but in many cases impracticable, methods of ventilating completely enclosed suits, none of which appear to have been successful. Samples of all available types have been taken. The most interesting appears to be a complete suit with a modified zipp fastener using a rubber gasket to give a gas-tight fit.

Amongst the devices tried for ventilating the suit was one in which bellows were fixed in the boots. The boots had a double sole hinged at the toe. Bellows fitted with a spring were sandwiched between the two soles and by the action of walking air was pumped through a container into the suit. In actual practice the device proved unsuccessful and it was found particularly useless on uneven ground. Another idea was to fix to the chest bellows with a container attached and to operate them by means of strings fixed to the arms. This again proved of no value.

No new types of gas planes were seen. One recent proposal was for the troops to cut their gas planes to a pattern

so that they could be converted into a form of cape. Details of the pattern have been obtained from Draeger-werk. The reason for this departure was that the gas plane was very difficult to adjust quickly to give protection against a low spray attack.

The casein/ammonia gas planes were introduced owing to shortage of other materials. They proved very effective against attack with phosphorus which, incidentally, the Germans considered was of more value against morale than in producing actual physical injury.

(B) Porous Clothing

German investigation of impregnated porous clothing arose from the capture of British documents from the French.

The work never passed the experimental stage and a general issue of impregnated clothing was not contemplated because of the shortage of raw materials for making the impregnants. In 1945, the German army was to receive a form of battle dress and impregnation would then have been reconsidered.

Jackets, trousers, underclothes and socks were treated, but the impregnation of the latter two was not at all successful because of the stiffness and general unwearability of the finished product. Two methods of impregnation were developed :-

- (i) Field Impregnation - aqueous dispersions using commercial emulsifiers (Emulphor).
- (ii) Laundry Impregnation - benzene dispersion.

Only a limited number of chamber experiments were carried out and the majority of the testing was performed in the laboratory on small pieces cut from the uniform. The leakage of mustard vapour through neck, arm and leg holes and through buttoned flaps was found to be a disadvantage although apparently no efforts were made to prevent this leakage. In fact the Germans went so far as to say that, owing to the bellows effect, the danger of vapour ingress was greater with impregnated clothing than with unimpregnated. The impregnated clothing afforded protection against small drops of mustard gas (Lost Nebel) but not against larger drops. Soldiers were averse to wearing the impregnated clothing because of its stiffness and smell and under certain circumstances the clothing caused dermatitis and cyanosis. In wear, the clothing lasted about four weeks, and in storage, about six to nine months.

It would appear that the German impregnated clothing was inferior to the British and American products, and taking

everything into consideration was not of much value.

No documents relating to impregnation have been discovered and, apart from one small bottle containing 20 g. of the impregnating agent, Selloxin 51, no chemicals, apparatus or clothing have been found which were obviously connected with any impregnating process.

Details of Experiments with Impregnating Agents

The Germans knew of the British and American impregnites E and CC-2 respectively, and they had made several similar components for trial themselves, e.g.

Selloxin 1 N-chlor-benzoic acid 2:4 dichloranilide

Selloxin 3 N-chlor-benzene sulphonic acid 2:4 dichloranilide

Selloxin 5 N-chlor-acetyl 2:4 dichloranilide

It was known that some of these impregnites could produce methaemoglobinaemia and toxic effects by skin absorption, e.g., Selloxin 5 produced up to 38 per cent methaemoglobinaemia, and 3 mg/kg. produced death in animals (rats, cats and guinea pigs) on subcutaneous injection. Cats have shown methaemoglobinaemia varying between 5 and 60 per cent.

To decrease the sensitivity to water, higher fatty acid derivatives of Selloxin were tried and with some success. Thus Selloxin 2011 (N-chlorinated 2:4 - dichloranilide of Stearic acid) with 15.3 per cent active chlorine was the best and was non-toxic to animals in doses of 3 mg/kg.

However, the raw materials to make this compound or other aniline derivatives were lacking and so melamin, $N_3C_3(NH_2)_3$ derivatives were studied, e.g.,

Selloxin 50 - Trichlormelamin

Selloxin 51 - Hexachlormelamin

Selloxin 52 - Dichlormelamin

Various routine tests were made with clothing impregnated with these materials. This routine is given below and illustrates well the methods used in assessing this kind of protection :-

- (i) Chemical penetration times - compared with unimpregnated clothing.
- (ii) Laboratory trials with human subjects. The forearms were covered with a rubber sleeve with a window into which clothing is placed. These cloth windows are exposed to H vapour (1290 mg.min/m^3 at 29°C).
- (iii) Field trials using human subjects wearing impregnated and unimpregnated trousers and jacket and standing down-wind of contaminated ground (100 g/m^2 of H or H/Arsin⁸¹). Chemical estimations of the vapour hazard were made.
- (iv) Because of the poor vapour returns, these trials were repeated in a warmer climate (Wasilika and Litra Sedes in Salonika, Greece). Various methods of impregnation, e.g., soaked or sprayed with Selloxin 52, new and old (3 weeks wear) uniforms, and unimpregnated new and old uniforms were used.

Because of the absence of vapour effects a second trial using two half-hour periods of exposure, the ground contamination being refreshed between these periods, was tried and again no effects were produced and so the contamination density was doubled and an hour's exposure tried. This time skin reactions were obtained, the erythema often not appearing for 1 to 2 days and not for 3 or 4 days in some cases.

The results of these trials may be summarised as follows :-

- (i) Selloxin impregnated clothing is no better than unimpregnated clothing. In fact, on the whole, unimpregnated clothing is better than impregnated clothing.
- (ii) Buttoned sleeves are better than bound sleeves.
- (iii) Used clothing is better than new clothing.
- (iv) Anti-gas ointment is better than cod liver oil, which in turn is better than vaseline.
- (v) CC-2 impregnated clothing, 2 per cent Selloxin (bucket aqueous impregnation) and 6 per cent Selloxin were also compared in a trial where five areas ($18 \text{ m} \times 50 \text{ m}$) with 20 m between were contaminated with H/Arsinol. The subjects lay in a shallow trench for two hours and at 25 m downwind of the contamination.

Sleeves and necks of the jackets were buttoned and ointment rubbed onto the hands. The uniforms were worn for a further two hours and then a hot bath was taken. Guinea-pigs were used as controls to test the vesicant power of the vapour. The results were poor since the vapour concentrations were not great enough and it was decided that workable H vapour concentrations could not be obtained at Raubkammer.

- (vi) Trials in the 300 m³ chamber at Spandau were therefore commenced. CC-2, Selloxin 52, and Selloxin 13 (nature unknown) - impregnated clothing was tested. The protection afforded by the Selloxin 52 clothing seems to have been small. Selloxin 13 clothing may have been better, but no impregnated clothing was used as a control and in this test, too, the Ct was lower.
- (vii) Trials at the Institute of Pharmacology and War-Toxicology of the Military Academy indicated that Selloxin clothing protected against fine drops of H. Therefore aircraft spray trials on impregnated clothing, the left sleeve of the jacket only being exposed to spray, were performed. The impregnation was a 6 per cent watery solution of Selloxin 52 and this was effective in protecting against 5 - 7 g/m² of H/Arsin^{ol}. (Any skin changes which did occur through the impregnated clothing were explained on the ground of faulty and uneven impregnation). This trial is described in detail in Appendix III.
- (viii) Laboratory trials, in which the left sleeves of worn field jackets, (impregnated with 4 or 6 per cent Selloxin 52) were contaminated with H (120 mg/120 cm²) and subsequently worn for 4 hours, indicated that such impregnation does not protect against 10 g/m² of H.

These results with impregnated clothing were considered by the Germans themselves to be particularly poor; if such poor protection were obtained under the artificial conditions of these trials, then the results in the field would be much worse. The difference between the poor field trials and the good laboratory results was explained on the following grounds :-

- (i) The "climate" under the uniform is different from that of the surrounding atmosphere. It is warmer and more moist, and hence the skin is more sensitive.

This warmth and moisture is supposed to be greater under impregnated than under non-impregnated clothing, under new than under old, and under bound than buttoned sleeves.

- (ii) There is also a "pump-effect" which draws vapour under, rather than through, the clothing so that the skin can never be completely sealed off from the surrounding atmosphere. This "pump-effect" is said to be more marked with German than with Allied uniforms.

In conclusion it may be said that the German-type uniform is not suitable for impregnation against H vapour. In 1945 a uniform designed like the British battle-dress was to have been produced. Impregnation of this may have been more successful. Impregnated German uniforms offer a greater degree of protection against H spray than they do to H vapour.

(C) Methods of Testing Porous and Impervious Clothing

The methods of testing porous and impervious fabrics are described briefly as follows :-

Porous Clothing

(i) Vapour

A specially constructed shallow glass basin was filled with an aqueous solution of methyl red or gold chloride of which the exact strength was not discovered, and the piece of cloth under test was sealed on to the top of the basin with paraffin wax. The whole was covered with a small bell jar from the top of which was suspended a piece of filter paper on which several drops of mustard gas were placed. The whole apparatus was placed in a glass cupboard thermostatically controlled at 30°C.

The penetration of the mustard vapour through the cloth was detected by the occurrence of a precipitate in the methyl red or gold chloride solution.

The air in the bell jar was claimed to be saturated with mustard vapour and the penetration times were of the following order :-

German impregnated uniform 7 - 8 hours

British " " 10 - 12 hours.

(ii) Liquid

The test against liquid was similar, a drop of mustard delivered from a 5 cc. pipette was placed on the fabric and the penetration time determined as above. The exact size of the drop could not be ascertained, but it was said to be 0.5 to 1 mm. in diameter.

The order of penetration times was approximately :-

German impregnated uniform - 2-3 hours

British " " - 4-5 hours

As far as could be ascertained only German and British woollen uniforms (trousers, jacket and underclothing) were tested against both liquid mustard and vapour.

Impervious Clothing

The test was the same as (ii) above with the following exceptions :-

- (a) A solution of methyl red and borax in water was used as the detecting solution. The two chemicals were supplied as solutions in small ampoules and the detecting solution was prepared from 10 mm. methyl red solution and from yellow to red.
- (b) It was ascertained that drops of 0.1 cc. of mustard and 0.1 cc. of lewisite were used.

Gasplanen and light and heavy rubber clothing and etc. were tested and the penetration times were of the following order :-

Gasplanen and light clothing ca. 3 hours

Heavy clothing ca. 5 hours

With the exception of the gold chloride solution the whole apparatus has been sent back to U.K.

5. Detection

The Germans relied largely on the Gasanzeiger as the standard instrument for gas detection in the field, but experimental work on modifications of the sampling tubes was still in progress.

Besides this instrument, a number of different kinds of detector paper had been developed, some for use by troops under active service conditions and others for experimental purposes in the field. Possibly as the results of information received from France, attention was being paid to automatic gas detection by means of photoelectric devices, which were also being applied for the quantitative assessment of detector papers exposed to gas concentrations in field experiments. As a general problem not particularly connected with C.W., they were greatly concerned with the danger from carbon monoxide and had developed several useful methods for its detection, although no new fundamental principles had been discovered. For detecting liquid contamination, the detector powders as used by the Germans are already well-known, but they were not entirely satisfactory under all circumstances. Detector paints were also receiving close study. Details of the latest features of the German methods of detection, together with information on the developments in hand or projected, are given below.

(A) Gasanzeiger

The construction and working of this apparatus is already well-known, but the following is a list of the markings on the tubes, the gases which they are intended to detect and the contents of the reagents in the tubes.

The following tubes had been approved and specified :-

No.1 ONE YELLOW RING.	Mustard and arsine.	Gold chloride, Potassium and naphthalene sulphochloramide.
No.2 TWO YELLOW RINGS.	Nitrogen Mustard	Potassium bismuth iodide.
No.3 ONE GREEN RING.	Phosgene and Diphosgene.	p-Dimethyl amino-benzaldehyde Dimthylaniline.
No.4 TWO GREEN RINGS.	Chloropicrin and Cyanogen chloride	Potassium cyanide, Dimethyl dihydro-resorcinol
No.5 ONE BLACK RING.	Hydrogen cyanide and cyanogen compounds.	o-Tolidine copper acetate.

No.6 THREE YELLOW RINGS. Lewisite and Osmium tetroxide,
 similar Benzidine acetate.
 arsenical com-
 pounds with
 the exception
 of arsine.

The specification for these tubes has been obtained from Draegerwerk (CIOS 8/77 and CW B23) and forwarded with the documents from this target. The first five were the normal issue. Tube No.6, although approved and specified, had never been manufactured and issued on a large scale because of the non-delivery of osmium tetroxide. This tube had been developed by Spandau and the experimental models were marked with ONE RED RING.

For several years, research had been in progress on the reduction of the number of ampoules in each tube and details are given below under the individual tubes. The introduction of simplified tubes, however, was not given any priority until recently when the shortage of labour limited the production of ampoules. This necessitated the reopening of the whole subject of dispensing with one and two ampoules in the tubes.

Glass tubes were first introduced experimentally in 1943. These possessed the advantage that the impregnated silica gel was far more stable in glass than plexiglass or trolitul tubes. They were, however, not available in large quantities because they had to be made by hand. Filter paper discs placed between the ampoules in certain tubes were for protection of the ampoules during transport.

Tube No.1. In the presence of arsine, the gold chloride impregnated silica gel turned violet in colour.

A new experimental tube had been developed by Draegerwerk (Figure I). The standard tube was rendered useless in cold climates because of the freezing of the contents of the ampoules. The ampoules containing water and methyl alcohol in the new tube did not freeze above -18°C.

Tube No.2. The original tube contained Dragendorff's reagent in the ampoule and a second layer of silica gel impregnated with mercuric chloride for the detection of arsine. Dragendorff's reagent was later replaced by pure potassium bismuth iodide which improved the stability and sensitivity of the test and the mercuric

chloride silica gel layer was removed; arsine was detected by tube No.1. Experiments with two ampoules of potassium bismuth iodide were carried out, but one ampoule was found to be sufficient.

Attempts were made by Auer to impregnate a solution of potassium bismuth iodide and aluminium chloride on the silica gel, but the impregnated gel was unstable in plexiglass or trolitul tubes. Iodine was liberated which coloured the tube brown. The impregnated gel was stable, however, in glass tubes.

Tubes No.3. About 1942 experiments were carried out successfully in order to :-

- (a) Provide p-dimethylaminobenzaldehyde and dimethyl aniline in one solution in one ampoule.
- (b) Impregnate the silica gel with both chemicals.

Tube No.4. The impregnation of the potassium cyanide on to the silica gel was unsuccessful in the plexiglass and trolitul tubes because of the hydrolysis of the cyanide by moisture absorbed through the walls of the tubes, but in the glass tubes the potassium cyanide impregnated gel was stable.

Tube No.5. This contained originally benzidine acetate and copper acetate but the former was replaced by o-tolidine. Attempts to impregnate copper acetate on the silica gel were commenced a few months ago by Auer.

Tube No.6. See remarks above.

Future development of Gasanzeiger. The Gasanzeiger was thought by those with service experience to be too slow and difficult to use under shell fire, and experimental work to render it more acceptable was being carried out. One suggestion being explored experimentally was to take the actual samples by absorption on silica gel and then to do spot tests as soon as possible afterwards. The silica gel was retained in a $\frac{1}{2}$ in. hole in a cardboard disc by two pieces of fine muslin stuck on either side and the gas sample was drawn through by attaching the disc to a hand pump. By this means, for example, it was found possible to detect 1 gamma phosphorus.

A further suggestion, although not tried out in practice, was to insert the disc into the end of a con-

tainer which could be connected to the facepiece by a long connecting tube. The container could be held in the air or near a source of vapour from contaminated ground and a sample taken simply by breathing. Another opinion expressed was that the Gasanseiger was unnecessary and all that was required was a simple detector for N-lost and arsine; other gases could be detected by sense of smell.

(B) Detector Papers

The following detection methods had been or were being investigated :-

Phosgene and diphosgene. The detector paper was prepared by soaking filter paper in a benzene solution of :-

5 per cent diphenylamine and

5 per cent dimethylaminobenzaldehyde

and dried. The colour change was from yellow to brown and the sensitivity, about 5 γ absolute. The paper was somewhat light and acid sensitive, and it was not specific. It was stored in a brown bottle.

This was the paper as issued to the troops, but for experimental purposes it was stabilised by the addition of 0.5 per cent pyrogallol to the impregnating solution.

Attempts to develop this paper for the quantitative estimation of phosgene were made, and the paper was placed in a plastic holder which was hung on a button (similar to the detector for arsine in the field). The detector paper was then covered with a paper impregnated from a solution of paraffin oil in carbon tetrachloride, different types of paper and strengths of solution being tried for various ranges of Ct's. With light sensitive papers, the paraffin oil paper was dyed red. In principle, this method was to be attempted with all non-persistent gases.

In the case of phosgene, note-paper was impregnated with paraffin oil as follows :-

0 - 1,000 mg.min./m ³	-	not impregnated.
1,000 - 3,000 " " "	-	10-15 per cent solution in carbon tetrachloride.
3,000 - 4,500 " " "	-	20 per cent solution in carbon tetrachloride.

The estimation was carried out by comparison with standards and worked best for exposure of 1 minute.

The method was fairly satisfactory except when investigations on peak concentrations were carried out, when it was found that animals died but the papers did not show the necessary Ct.

Hydrocyanic acid. An experimental paper was prepared as follows:-

Solution A. 0.5% copper sulphate in water.

Solution B. { 7 g. potassium hydroxide and
 { 3.5 g. sodium sulphite anhydrous
 { in 60 cc. water:
 { 2, 3 or 5 gm. phenolphthaline in
 { 40 cc. alcohol.

The paper is impregnated in solution A, dried, impregnated in solution B and then dried quickly in hot air. For quantitative estimation, the paper is impregnated in 5 per cent paraffin oil in carbon tetrachloride. If rolled tightly the paper is stable for 2 weeks and its keeping properties are improved by the presence of benzene vapour.

The colour change is from white to violet and the paper is sensitive to 5 mg/m^3 in one minute. It is light sensitive and is affected by cyanogen chloride and nitrogen dioxide.

The sodium sulphite is added as a stabiliser and the copper sulphate can be replaced by the acetate.

Tabun can be detected with the same paper. The hydrocyanic tube in the Gasanzeiger can also be used for this substance; sensitivity 10 mg/m^3

Soman (Sarin, Tabun). Experiments on the detection of Soman were carried out by absorption in a 1.0 per cent solution of o-tolidine in alcohol or benzene followed by the addition of perhydrol (30% hydrogen peroxide) and hydroxides, the best being ammonium hydroxide. A dark yellow to brown colour developed in the cold. The method was claimed sensitive to 10 gamma absolute. No paper had as yet been developed, but experiments have been carried out.

Arsine. (Nachweispapier A). Paper impregnated from 5 per cent mercuric chloride in alcohol, dried, impregnated from 5 per cent trichloroacetic acid in water and dried. Colour change is yellow to brown and sensitivity 5 gamma absolute in 3 minutes. The paper was stable after issue to troops for 8 to 12 months. During quantitative estimation, a red coloured paper for light protection is unnecessary.

Cyanogen Chloride. 'YY' Dipyridyl is used but is difficult to pyridine itself is unsuitable because it evaporates. The paper is prepared as follows :-

Solution A. 5 per cent dipyridyl in alcohol.

Solution B. 2 per cent p-aminophenol (recrystallised from benzene) and 20 per cent glycerin in alcohol.

The paper is impregnated successively from solutions A and B with intermediate drying. It keeps fairly well but during storage may turn slightly yellow and later pink; it is stored in a brown bottle. The colour change is from white to blue and the blue colour is only stable for 15 - 45 minutes. The paper is claimed to be specific to cyanogen chloride and does not react to hydrocyanic acid. It is, however, now very sensitive, 25 mg/m³ in 1 hour.

For quantitative estimation, no paraffin covering paper is necessary, but during exposure, the holder is inserted in a cylinder of red paper with perforated holes to prevent fading in sunlight.

Nitrogen Mustard (Stickstofflost). Several papers were developed for this detection :-

(i) A paper was impregnated from the following solution :-

2-3 per cent potassium bismuthiodide ($K_3(BiI_4)$), about 1 per cent hydrochloric acid, 5-10 per cent glycerin in water with the addition of potassium hydrogen sulphite. The colour change was from yellow to red.

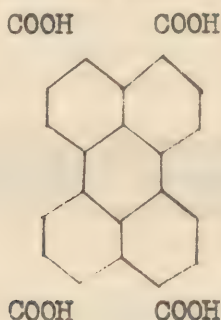
(ii) A paper was impregnated from a saturated solution of hexanitro diphenylamine (sym). in acetone. It changed colour from yellow to red and was claimed to be very specific

(?) and stable for 2 years. It also reacted with liquid Tabun.

- (iii) Paper was impregnated with 1 per cent p-dichloroquinone in acetone and spots of nitrogen mustard on the paper turned blue in sunlight or in blue light. It did not react with the vapour. It was claimed to be specific and probably stable.

Night Detector Paper (Nachtsprüher). The paper was impregnated with a 0.1 per cent benzene solution of Fluorol 188 (I.G.) and dried to give a pale yellow colour. On contact with any ground contaminant, the paper gave a bright green fluorescence when exposed to blue light. Several blue filters were tried but the best result was obtained by dyeing the Klarscheiben with Victoria Blue Base N.R. (I.G.) and using an ordinary electric torch. This has been approved by Insp.9. Samples have been obtained.

The formula of fluorol was not known, but it was believed to be a single compound and a derivative of stilbene, the formulae suggested being an ester of



(C) Universal Automatic Detector for War Gases

This was arranged to work by means of a photocell and was only in the experimental stage. The gas was sucked into the apparatus and divided into two streams, one of which passed through a heated quartz spiral and the other passed on unchanged. Both streams were then mixed and allowed to impinge on one half of a travelling detector paper impregnated with congo red and mercuric chloride. A beam of light was reflected from the paper on to a photocell connected to a galvanometer. The beam was arranged either to oscillate backwards and forwards across the paper or it could be rotated to describe a cone thus covering the whole of the width of the paper. Any change

in colouration of one half of the paper caused a change in the galvanometer reading.

(D) Automatic Recording of War Gas Concentrations for Field Experiments

Developmental work was being carried out on the detection and continuous recording of field concentrations of chloropicrin and hydrocyanic acid by colour changes on a travelling ribbon of paper. The work was based on a recorder produced by the French in 1939 for estimating phosgene. Two types of apparatus were being developed. In one, a photocell and light source are incorporated so that readings can be obtained directly in the field, whilst in the other the moving ribbon is exposed in a separate apparatus in the field, and is run through a recording apparatus in the laboratory. Samples of both types are being sent back to U.K. for examination and report.

The two following papers were developed :-

(i) Chloropicrin paper. The following solutions were prepared :-

3.8 gm. tetrabase (tetra methyl diamide diphenyl methane)
2.8 gm. diphenylamine
0.5 gm. dimethyl amido benzaldehyde
1.7 mgm. hexanitro diphenyl methane
150 cc. dried benzene.

A not too finely porous paper strip was impregnated carefully in this solution and dried quickly away from sunlight. The contaminated air was drawn through a tube heated to 550-600°C. and then allowed to impinge on a small area of the paper strip. The paper turns more or less blue, but the blue colour slowly fades. With freshly impregnated paper, the sensitivity is 5 mg./m³.

(ii) Hydrocyanic Acid Paper. This paper was impregnated from a solution of the tetrabase (above) and a copper salt in acetone/benzene. The most suitable copper salt was a mixture of acryl- and oleic derivatives in equal proportions.

To increase the sensitivity, a plasticiser must be added, the best being found to be :-

Diethylphthalate or
Crataegon from Schimmel, Leipzig.
A fine porous paper was used as with chloropicrin.

The paper is stable for 2 months and possesses a sensitivity of ca. 50 mg. absolute.

(E) Detector Powders

The German troops did not like the powder provided for detecting liquid contamination since it was difficult to use in wet weather and was ineffective when applied to contamination which had developed a skin through ageing. Furthermore the powder reacted to oils and fats. In consequence there was a demand for a more sensitive powder with a better colour reaction which was not affected by water and which would show up old contamination. This problem was not solved. They found that mixing with talc made the powder unreactive to water, but it still remained ineffective against gas which had formed a skin. The use of a detector paper might have solved the difficulty, but Insp.9 rejected this alternative.

(F) Detector Paints

The standard German detector paint was designated K2L (Spürlack). It was rose coloured and differentiated between mustard, nitrogen mustard and oil. Mustard produced a deep red to violet colour in 10-15 seconds, nitrogen mustard, orange red and oil, no (or very slow) colour change. It consisted of the following ingredients :-

- (a) Paint base - chlorinated rubber or chlorbuna
- (b) Solvent - xylol, solvent naphtha
- (c) Plasticiser - Colophen A 60 (I.G.)
- (d) Indicator - chrysoidin (yellow brown) I.G.
- (e) Colour solution - I.G.1 (violet powder)
- (f) Titanium dioxide.

The paint worked satisfactorily except with dirty or acidic contaminants. When the British paint was captured,

it was tested and the change from khaki or green to red was much preferred. The Germans specified a similar type of paint and apparently an order was given for its manufacture, but none had yet been delivered.

(G) Detector Dogs

A new departure begun in 1937 was the training of dogs to delimit areas contaminated with mustard and other persistent gases. These dogs, known as "Spürhunde", were trained under the direction of Dr. Rudolf Kukh, head of RIII, who had made a speciality of the subject. They could work either upwind or downwind of a contaminated area by sniffing the ground and they would stop whenever they reached any place where there was a trace of gas. A minimum of 8 weeks training was required, but 6 months was preferable. They required a "refresher" course if they had not been used for detection purposes for more than 6 months. The German sheep dog, or any dog which was not too highly bred, was suitable for training. So far dogs had only been trained to detect mustard and nitrogen mustard. This method was, however, not favoured by the troops.

(H) Carbon Monoxide Detection

Four methods of detection seem to have been available.

- (i) Kohlenoxydanzeiger. This consisted of a pump, of design similar to that in the gasanzeiger, and special detector tubes, which contained a layer of purified silica gel (Reinigungsmasse) and a layer of silica gel impregnated with sulphur trioxide and iodine pentoxide, (The preparation of this tube is described in detail in the investigation report on Draegerwerk). The Reinigungsmasse was not entirely satisfactory for the removal of petrol fumes and an additional filter had been approved but not yet manufactured or issued. This is shown in Figure II. A "Satz Vorschaltrohre für Kohlenoxydanzeiger" (connection tube set for CO detection) was to contain 20 of these tubes, 3 pieces of connecting rubber tubing and an opener for the tubes, and was only to be issued to Panzertruppen. Forts were to be provided with the Kohlenoxydanzeiger only.
- (ii) CO Detector Paper. In 1939-40, papers impregnated with palladium chloride were issued but

these were unstable and were withdrawn. The Satz Kohlenoxydprüf Papier 42 was then introduced which contained four boxes of filter paper strips, two small bottles with 0.1 per cent (?) solution of palladium chloride in water with the addition of sodium acetate, a leaflet of instructions and a plastic holder for suspending the paper from a button.

- (iii) Semi-Automatic CO Detector. This was designed for use in tanks and enclosed spaces and works off a 12-volt battery. It is illustrated diagrammatically in Fig.III. Air is drawn into a long narrow sintered glass funnel, the stem of which contains iodine pentoxide. The sintered glass is impregnated first with silver nitrate, which is reduced to silver, and then with iodine. In the presence of CO, the sintered glass funnel turns red. In juxtaposition to the detector is a blank impregnated sintered glass funnel over which can be superimposed a red filter, and both detector and blank sintered glass funnels are observed and compared through two small round glass windows. Considerable research had been carried out with this apparatus in order to determine the optimum working conditions. Complete details were not obtained, but an apparatus has been sent back for examination. The reaction on the sintered glass plate is reversible and the red colour, formed in the presence of CO, fades in the absence of the latter. Only 30 models of this apparatus were probably made.
- (iv) Automatic CO Detector. Research was in progress on the development of automatic detectors based on the reaction between carbon monoxide and hopcalite. In one type, the temperature change was recorded by an air differential thermometer and, in the other, by the change in resistance of a wire coil wound round the glass hopcalite container. Two examples of the former type are being sent back from Raubkammer and full details were obtained later from Draegerwerk, but no further information about the latter type was forthcoming.

(I) Miscellaneous Items on Detection

- (i) IIIL was also responsible for the examination of captured ointments, detection equipment, etc. Work in progress which had been transferred from Spandau included the examination of the American Kit (BAL ointment and A/G ointment M5), the British A/G ointment No.5, the American Kit Water Testing, the American Detection Kits M4 and M9, the Detector Paint M3, and British detector paints. Routine testing of German detection equipment which had been stored or issued to the troops was also being done.
- (ii) The following samples of chemicals used in detection are being sent back to U.K. Phenolphthaline, γ ' dipyridyl, hexanitrodiphenylamine, Victoria Blue N.R., chrysoidin, I.G.1, and rose and green detector paints.

6. Decontamination

(A) Routine Methods used at Raubkammer

Rubber articles were decontaminated from mustard by soaking in large tubs in 2 per cent chloramin T solution for 24 hours. The solution was initially heated to 50°C. and then allowed to cool to room temperature. The articles were then removed, rinsed with a 2 per cent chloramin T solution, rinsed with water and dried.

The treatment for N-mustard was similar, except that the chloramin bath was maintained at 40°C.

Losantin was not used for two reasons :-

- (a) blockage of the drains occurred, and
- (b) the Losantin weakened the stitching of the clothing.

The washing machines in RIII were used exclusively for washing workers sweaty underclothing.

(B) Experimental Work

On the experimental side, the work progressed on the usual lines and no new or startling developments were apparent. Practically the complete set of papers on decontamination was retrieved and will be reported on in

due course. It is only necessary, therefore, to give a very brief sketch of the investigations carried out.

Decontamination of the following articles had been under investigation :- Rubber clothing including gloves and boots; Leather; Gas Masks; Uniforms both woollen and cellulose.

The following gases were examined as regards decontamination :- Mustard; Nitrogen Mustard; Arsinol/Lost (OA), Zänlost and enemy war gases. The following methods were examined for their applicability to vehicles, plant, etc.:- 2 per cent Chloramin or Losantin solution; Boiling and warm water; Hot air, hot damp air and superheated steam; Washing.

The applicability of the different methods to the various articles is listed below :-

Rubber Clothing (heavy and light) and Gasplanen (where applicable) 2 per cent chloramin or losantin solution at 50°C. This was not entirely suitable for troops because care was needed in control of the concentration and temperature and too strong a concentration attacked the stitching - Boiling and warm water.

Leather. Standing in water at 50°C. for 12 - 24 hours - Hot air, 95°C. for 24 hours.

Gasmask, GM30. Similar to leather viz. Water at 60°C. Hot air, 95°C.

Gasmask, GM38. Boiling water for 1 hour.

Uniforms

- (i) Boiling water.
- (ii) Washing by the following routine :-

Breakdown 40°C. 15 minutes.

Rinse 40°C.

Main wash 50°C. 1½ hours with soap or other detergent.

One or two rinses at 50°C.

This was claimed to be satisfactory for most contamination up to a density of 100 g/m². For Zänlost, a second

main wash was included for 1 hour and claimed to be satisfactory with 100 g/m² contamination.

(iii) Hot air, etc.

6-8 hours, dry hot air circulated at 120-130°C.

4 hours, alternate dry and damp air circulated at 120-130°C.

1½ hours, alternate hot air and steam circulated at 100°C.

20 hours, dry air static at 100-120°C.

Hot air was of no use with arsenical vesicants.

A Russian method had been tried with some success. 120 uniforms were packed tightly in a container or rammed into a pit and ammonia and ichthyol were passed in by means of a pipe from a boiler. Very good results were obtained; the process was complete in 3 hours, and the uniforms could be dried in 6 hours.

Testing of Decontaminated Clothing. The decontaminated clothing was tested by the usual methods :-

Chemical (microchlorine for mustard, microarsenic for lewisite and Gasanzieger).

Animal trials.

Wearing trials.

A method was developed for testing for arsenic on contaminated garments by pressing a piece of cleaned zinc foil (sandpapered) on to the contamination and heating with a blow lamp. A stain on the metal developed, grey, brown, or black according to the degree of contamination. Grey stain was considered almost safe.

This method has been developed into a field testing kit.

The detergents investigated in the place of soap in the washing method were of the following types :-

Mezzo sulfo sauresalz.

Laventin.

Emulphor.

Lignin sulfosauresals (Zellstoff Fabrik).

(C) Decontamination of Drinking Water

A copy of a pamphlet dealing with German methods of purification of contaminated drinking water has been obtained. One method advocated was to pass the water through layers of silvered charcoal to which freshly precipitated iron oxide had been added to deal with arsenicals. If on test the water was found not to contain more than 20 Y of As per litre, it was considered fit for drinking. The method suffered from the serious limitation that the charcoal rapidly became exhausted especially when the water was dirty, and there were not sufficient supplies available for large scale decontamination. The Military Academy developed another and more economical method using active charcoal which was not so good, but even then the supply was inadequate.

The Germans were worried about the effects of gas on the water supplies of big cities like Berlin and thought it likely that reservoirs might be subjected to gas bombing. The problem was then passed to the Reichsanstalt für Wasser und Luftgute at Berlin Dahlem under the direction of Prof. Hase. He worked out a method using hypochlorous acid which was effective in the case of mustard and lewisite, but it was not of much value for N-mustard. It was also of no use for chloropicrin, and arsenic still remained in the water unless the iron oxide treatment was applied. When properly treated, there was no harm in drinking the water, but it did not taste well. The experimenters tried it themselves for a few days without ill effects. Water treated by this method after contamination was then given to the prisoners in the Dachau concentration camp over a period of three weeks and they did not notice anything unusual. Wa. Prof. 9 did not take part in any of these experiments.

We are indebted to Lt. H.E. Hudson Jr., U.S. Army, for the following information about two water purification units found at Raubkammer :-

In the RIII area was found one trailer-mounted water purification unit and a separate unit for application of chlorine to water contaminated with chemical agents. These were parts of two rival methods for water decontamination. According to those interviewed, the two sets of equipment were tested at Raubkammer under the aegis of the Reichsanstalt für Wasser und Luftgute and the Heeressanitäts

Inspection Dureau, both Berlin agencies.

The tests were supervised by a Dr. Gmeinhardt of the Sanitäts Bureau, and Prof. Hase of the Reichsanstalt and involved waters contaminated with Lost and Winterlost. The chlorination scheme failed to produce palatable water, while the trailer mounted unit was considered a success.

The trailer-mounted water purification unit is capable of operation at rates of from 350 to 2100 litres per hour. The unit, designed by Seitzwerke, Bad Kreuznach, includes a gasoline engine-driven reciprocating pump, a mechanical feeder for adding a mixture of Kieselguhr and pulverized active carbon (Hydriffin E8), a preliminary filter equipped for manual sludge removal, two granular carbon (Hydriffin WSII) beds, and a plate and frame filter press. The unit is well designed and sturdy, but complex. The manufacturer stated that 3 were built, and 250 ordered but not fabricated for the German Army.

No concrete information on the decontamination of Tabun and Sarin in water supplies was secured. It was indicated that, in dilute solutions, these agents would hydrolyse more rapidly than trichlortriethylamine, and more slowly than mustard gas. Sarin was thought to be completely soluble in water, Tabun less so. The minimum rate of hydrolysis was said to be in the neutral pH range. Both were rapidly hydrolysed by strong alkali.

(D) Decontamination of Foodstuffs

Little direct information on the decontamination of foodstuffs was obtained and a full picture of German methods will have to await examination of the documents on decontamination. It may be noted that the method for decontaminating flour was similar to that of the British, viz., immersing the sack in water and later pouring out the loose flour from the crust formed by the penetration of water from the outside of the sack. Contaminated oats for horses were put in sacks in a vat and water was led in from below and allowed to run continuously. Decontamination was complete in 24 to 36 hours and the method was found suitable for mustard, lewisite and nitrogen mustard. Horses did not like oats after treatment if they had been contaminated originally with lewisite.

(E) Skin decontaminants

For decontamination of the skin washing with soap and water is considered to be the best method especially if carried out within a few minutes of contamination. British A/G Ointment No.5 and the American No.5 Ointment are also thought to be excellent decontaminants. In addition the Germans consider that these ointments give excellent protection against H vapour. In fact, the "jelly type" of ointment, such as M5, is considered to be better than any equipment or impregnation yet devised for protection against H vapour. The Germans themselves would have liked to make an Ointment like M5 but were short of the necessary thickening agents.

It was considered extremely difficult to decontaminate all the body with an ointment, and so, for this reason, a decontaminating soap was introduced. M.S. Soap (Mersol) made by I.G. Farben was the soap finally chosen, and, as is known, issued to the Army. It was intended for use by medical officers, decontaminating troops, and at decontaminating centres. They claim that it is good against all vesicants, and is effective against H even 10 minutes after contamination. Dr. Postel did the original decontamination experiments at Spandau on guinea-pig skin and using 1-10 mg. of vesicant per 5 cm² of skin.

As regards nitrogen mustard, it was found that the weapon decontaminant was better for the skin than the actual skin decontaminant. It was therefore suggested that the soldier should determine the nature of the contamination before deciding on the agent to use. An impregnated cotton wool pad with an orange red band round it was to be used for swabbing off the free liquid contamination. If the pad turned the same colour as the band, then the liquid was nitrogen mustard and the weapon decontaminant was to be used. The device was not put into service.

Some work had been done before the war by Dr. Oswald at Wurzburg on the possibility of obtaining a readily available decontaminant for H. Various ashes, mixed with water to make a paste, were tested on rabbits ears using a contamination of 5 mg. of H. The paste was applied thickly, left on for 5 minutes and then washed off. Coal ash was found to be no good, but wood ash, peat ash, lignite, etc., were effective. The control decontamination was done with bleach paste or by washing with soap or soft

soap. The ashes were better than the soaps but not as good as bleach paste.

Other miscellaneous points of interest are: The Germans were short of containers for Losantin, and glass containers with zinc tops were provided for military use and all glass containers and tops, for civilian purposes. The Losantin kept well in the containers with zinc tops, but not so well when the tops were of glass.

For phosgene oxime, dilute ammonia was recommended to alleviate the pain from the burns. Phosphorus burns were treated with copper sulphate, but later it was found that sodium bicarbonate was better.

(F) Decontamination of Vehicles

The information received covered aspects most of which are already well-known to us. A few points of interest did arise. It was noted that there were two types of vehicles for clothing. There was a troop decontamination vehicle, the TEK, for normal clothing. Each division had one and it was under medical supervision. The smoke troops also had their own unit decontamination vehicle which was intended for heavy clothing only, with a capacity of 20-30 suits per hour. Normal clothing could not be handled and was passed to the TEK for decontamination. The smoke troops' vehicle could also provide bath water by circulating water from a tank through the radiator of the I.C. engine, which was running continuously, and back again to the tank.

In at least one type of TEK, the water was heated by a novel method. There were two tanks each of 500 litres capacity at the back of the vehicle. Water was circulated from the tanks through an impellor mounted on the crankshaft in front of the radiator, and then back again to the tanks. Heat was generated by friction in the impellor much in the same way as in a water brake on an engine test bed. The engine developed 100 H.P. and could provide 1000 litres of water per hour at 60°C. Eventually the method was abandoned owing to shortage of petrol.

7. Description of RIII Raubkammer

RIII consists essentially of a large and elaborate centre for the issue and maintenance of anti-gas equipment for field trials and for the decontamination of personnel, anti-gas

clothing, vehicles and horses. The layout of the buildings is shown in Fig. IV.

RIII, Buildings A and B.

Building A provided showers and baths for men, with appropriate locker and dressing rooms, large wooden tubs for decontaminating anti-gas clothing, and washing machines for dealing with ordinary dirty clothing. There were also very elaborate arrangements in tiled rooms for drying decontaminated rubber clothing by hot air. Each item of clothing was date marked by a special machine after decontamination. The S.W. part of the building contained machines for repairing damaged clothing. Under the building were large furnaces and boilers for providing hot air and water.

In the attic above the building two set-ups for opening used containers were found. One is a converted seaming machine in which one of the seaming wheels is replaced by a circular cutter. The other works on two shafts, one holding the container which can be moved in two directions, i.e., in line with, and at right angles to, the shaft, and the other being motor driven with a small circular saw. The container is brought up to the saw at the approximate position and slowly rotated by a hand screw until the complete circumference is cut.

It appears that III L of Spandau was in the process of moving into the building as one of the cellars was full of crates of apparatus, only a few of which had been unpacked.

The apparatus was mainly non-specialised, consisting of the commoner types of chemical laboratory glassware with a selection of physical instruments such as voltmeters, anometers, pyrometers, etc. Two of the smaller rooms on the ground floor in the building were already occupied by III L. In one, several boxes of photographic negatives and files of prints belonging to III L were found. These were photographs mainly of British, Russian and German Anti-gas Equipment and did not appear to be of great importance except from an historical viewpoint, but they were sent back to U.K. for more detailed examination.

In the other room used as an office by Dr. Meiner of IIIcL a practically complete set of documents on decontamination was found and was sent back to U.K. for examination.

Building B - The basement of this building consisted of a number of store rooms and a small laboratory fitted up for IIIcL. One large room was full of quantities of several different types of heavy anti-gas clothing, rubber boots, gloves, etc. All were carefully stored and arranged. A small room held a large stock of rubber garments for protection of limited areas of the body. A second small room contained stocks of uniforms, whilst a third held reserve stocks of spare containers and respirators, including a number of British ones, respirator repair outfits, boxes of detector tubes, etc. There was a small laboratory in which there was a stock of chemical glassware and also apparatus which had been assembled for testing the charcoal from filtration units. Finally a fourth room contained a stock of instruments for the measurement of air flow, resistance, etc. Apparatus for carrying out the D.C. test for filtration units was found in this room. All this material belonged to IIIcL.

The ground floor comprised recreation rooms, a row of offices, a respirator store and rooms for self-contained breathing apparatus. There was also a small museum of facepieces and respirators.

The offices contained a certain number of documents on defensive equipment which were sent back to U.K. The respirator store contained numbers of different kinds of service and civilian respirators, spare containers, industrial containers, gas planes, repair outfits, spare parts, etc. The service facepieces consisted of the GM30 and 38 types together with about the same number of the GM43 type (the new facepiece with expiratory valve with mushroom shaped cover over the nose for improved speech transmission). Three

modifications, presumably experimental, of the GM38 were seen and samples obtained. A sample GM44 was also obtained which consists of modifications of the GM38 mainly to improve it for use with optical instruments. A microphone attached to wire and jack was obtained. This is for fitting on to the facepiece attachment.

Orinasal masks made by both Auer and Draeger were found, mostly with light containers for dust protection only, there being a large supply of spare filters available as refills.

A large number of containers were seen of the FE37, FE41 and FE42 types and also industrial types for use against HCN, ammonia and CO. There was no indication of any new development or any unusual types. An FE38 container was found and retained for examination as it had not been met before. It was in no way abnormal externally.

A large laboratory was used to store and issue the standard self-contained breathing sets and there was a well laid-out bench for testing and recharging exhausted cylinders.

The first floor included two small chemical laboratories which had been taken over by III L for work on detection. Each contained a complete field laboratory (Feldlaboratorium) and general development work on this was in progress. The work in hand embraced the examination of captured ointments, detection kits and paints, development of paints, improvements in the carbon monoxide tester and in the gasanzeiger, routine testing of German gas detection stores and development of new methods of detection. One laboratory contained an all-glass gas mixing apparatus for establishing different concentrations of gases for testing detectors.

Adjoining the chemical laboratories were two large attics. One was used as a store for clothing and the other contained a large amount of collective protection equipment and apparatus for testing its performance. The equipment included 1.2, 2.4, and 10 m³/min. units with fans and motors, experimental tank filtration units, hand operated blowers, flow meters, dynamometers, an ultramicroscope, etc.

Building C is a gas chamber and presumably was used for testing the fit of facepieces before field trials.

Building D was used for hot air decontamination. It contains three chambers lined with tiles and asbestos sheeting, fitted

with slots so that an even flow of hot air can be obtained at all levels in the chamber. One of the chambers is sufficiently large to accommodate a 3-ton lorry.

Buildings E are store houses of no particular interest.

Building G is a covered wash down.

Building H is a garage for decontamination vehicles.

A small distance away from the main buildings there is a trough (F) for decontaminating horses. Apparently the horses entered from the range and, after having harness removed, walked through the trough. When they emerged they were tethered and scrubbed.

Investigation of Chemical Warfare Installations
in the Munsterlager Area, including Raubkammer

APPENDIX III

THE MEDICAL ASPECTS OF GERMAN CHEMICAL WARFARE

1. Introduction.
2. Physiological methods of tests.
3. Mustard gas and other vesicants.
4. Phosgene oxime.
5. Phosgene and other lung irritants.
6. HCN and CNCl.
7. Arsine and Aeroform.
8. The harrassing agents.
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10. The physiological results of field trials performed at Raubkammer.
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13. Description of the Sections of Raubkammer that pertained to the Medical Aspects of C.W.
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APPENDIX III

MEDICAL ASPECTS OF GERMAN CHEMICAL WARFARE

1. Introduction

The Germans placed great dependence upon the physiological effects of war gases on animals in the evaluation of the potential use of any compound or mixture. Most of the tests were carried out using standard test animals but the effects upon man were observed whenever it was possible to do so; the accidents in factories, laboratories, etc., offered the opportunity to study the effects as well as the proper treatment.

The research was carried on by various agencies within the Army and at certain Universities.

The following personnel were interrogated.

Oberst Hirsch	-	Wa Prüf. 9.
Oberstabsarzt Jansen	-	
Stabsarzt Prüsener	-	RV and RVII, Raubkammer and previously VII L, Spandau.
Oberstabsarzt Oswald	-	Senior Medical Officer, Raubkammer.
Dr. Nobbe	-	RVI, Raubkammer.
Dr. Strasser	-	RV, Raubkammer.
Dr. Gerhard Böttger	-	VII L, Spandau.
Dr. Winkler	-	V L, Spandau.
Dr. Wagner	-	Gr V, Wa Prüf. 9.
Stabsarzt Heinz Kruse	-	VII a L, Spandau.
Professor Klieve	-	VII c L, Spandau.
Hauptmann Marthens	-	Medical Officer, Dyhernfurth.
Hauptmann Jansen	-	Medical Officer, HMA, Munster Ost.
Dr. Eberhard Postel	-	Pharmacology and War Toxicology Department, Military Academy, Berlin.
Professor Wolfgang Heubner	-	Pharmakologische Institute, Frederick Wilhelm Universität, Berlin.

Important personnel still to be interviewed include

Professor Wolfgang Wirth	-	Chief of Group VII, Wa Prüf. 9.
Professor Wimmer	-	Strassburg University.
Professor Picker	-	Strassburg University.
Professor Flury	-	Würzburg University.

Toxicity Figures

The accepted (1944) German toxicity figures are given here. Figures differing from these will be found in various Sections of this report; this difference is probably due to the fact that the latter represent the work of individual investigators.

Agent	Minimum Detectable concentration, mg/m ³	Intolerable Conc. mg/m ³	Lethal Ct. mg.min./m ³
CN	0.3	4	500
Dick	0.8	10	3500
Clark I	< 0.2	1	
Clark II	0.005 (Smell)	0.25	
	0.01 (irritation)		
Excelsior	< 0.05	0.25	
Phosgene	0.5 (Smell)		1000
			3000
Adamsite	< 0.5	1-3	
Diphosgene	0.1 (Smell)	75	2000-3000
Klop	< 3	25	6000-12000
Arsine	30-50		6000 (conc 200 mg.)
			(Dog)
HCN	< 10		1000-3000
			(conc. 50-100 mg.) (Cats)
CNCl	1-2	150-200	1200 (Cats)
			10,000
Tabun	0.006 (Smell)		(Guinea pigs)
			400 (conc. 50 mg.)
			300 (-100mg)
Sarin	Odourless		100 - 150
H	pure -0.2 (smell)		700 - 1000
	techn. -0.01-0.02 (smell)		
H/Arsenol			
HT			
H-homologues			1 - 2000
H/Anthraz-enol			
HN-3			
Pfiffikus		10	700 - 1000

Another table relates lethal dose for man with the time of onset of symptoms and the time of death.

Agent	Time of occurrence of		Total dose/65 kg. wt. (Breath- ing 40 L/min.	Lethal Ct. mg. min/m ³ .	Exp. Time min.
	Illness	Death			
Phosgene	3-4 hours	4 hr. - 3 days	40 mg.	1000	10
H	3-4 hours	1 - 7 "	60-	1500	15
Arsine	3-5 hours		115 mg.	22500 (at once) 1500- 3000 (5days)	30 30- 60
HCN	(10-20 mg/m ³)	Immediately (1 - 2 min) harmless	80-100 mg.	2000 900	10 3
Tabun		Immediately (1 - 2 min)	11 mg.	274	2

2. Physiological Methods of Testing

Only new methods or methods peculiar to C.W. Research are discussed here.

(1) Testing the Vesicant Power of a liquid C.W. agent

The old method was to dissolve the agent in 15 mm³ of benzene and then to apply this to the skin by means of pipettes. However an exact area of skin was not contaminated by this method and so the following method was devised :-

1 - 3 mg. of vesicant was weighed onto a 1 sq. cm. glass plate held in a cork. The glass plate is then placed on the end of a spring-rod and wiped across the flexor surface of the forearm of the shaved skin of an animal. By this means it was hoped to contaminate a given area of skin (approximately 1 sq.cm.) at the same constant pressure. For strong vesicants 0.1 mg were used for comparison purposes.

This method of contamination was criticised by the Germans themselves on the grounds that a constant reproducible density of skin contamination could not be obtained by the "wiping technique". A rod method of contaminating was suggested - similar to the Edgewood rod method - but not adopted.

In assessing the value of a vesicant, the time of appearance of the various stages of the skin lesion, the size of the skin lesion and the time the lesion took to heal were noted. The latter two observations were considered to be the most important.

If decontamination methods were to be assessed, then the decontaminating agents were applied at various time intervals after contamination.

The penetration of clothing by drops of liquid vesicant was determined by placing them either on the forearm of a man or onto the shaved skin of an animal. In some cases the left sleeve of a uniform jacket was contaminated to a given density with drops of vesicant and then the jacket worn for 4 hours. The fact that the penetration of clothing in the field might be affected by the terminal velocity of the sprayed droplets does not seem to have been appreciated or at least was not assessed.

Because it was necessary to do many of the vesicant tests on animals, the relative sensitivity of the skin of different species to a 1 per cent solution of H was determined at Spandau. The following results were obtained.

Horses, rabbits	-	100 per cent react
Dogs, men	-	83 per cent react
Mouse	-	70 per cent react
Guinea-Pig	-	33 per cent react
Rats	-	30 per cent react
Apes	-	22 per cent react

Hence dogs were considered the best animal for comparison with humans and then only when taking the skin between a dog's toes.

The danger of interpreting animal data too literally was further illustrated by the observation that all gases which contain arsenic react more strongly on animal skin than did pure H. However, on human skin, pure H was more potent than the arsenicals.

(2) Penetration of impregnated and unimpregnated clothing by H vapour - Laboratory technique: The clothing (2 layers - uniform cloth and skirting) was either placed directly on to the forearm or else the forearm was covered with a rubber sleeve, which contained a window into which the clothing to be tested was stitched. The clothing was then exposed to H vapour by placing it over the top of a glass tube. (The usual Ct was 1290 mg.min/m³ at 29°C.).

(3) Persistence of Liquid Vesicant in the Field:- This was assessed by

(a) Guinea pigs with shaved bellies (clothed and unclothed) were placed in contact with the ground for 30 minutes.

(b) Men wearing patches of 2 layers of clothing (jacket and shirt) over the knees and elbows, crawled over the contaminated areas. The patches were then removed and strapped on to shaved guinea-pig bellies for 3 hours.

(c) The guinea-pig method (a) was considered to be too inaccurate because of the unequal distribution of H on the ground. Therefore a hammer (handle 1 m. long and head 0.15 m long) with a piece of clothing over the head was used. The clothed head of the hammer was brought into contact with the ground 100 times at random over the area. The contaminated cloth was then placed on a shaved rabbit's belly for 4 hours.

(4) Penetration of Clothing (impregnated and unimpregnated) and of ointment by vesicant-vapour in the field.

Men were clothed in underwear, a two-piece outer uniform, boots, socks, field equipment, and mask, the face and neck not being covered by the facepiece. Their hands were anointed with various types of ointment; in some cases the cuffs of the sleeves were tied with tape and in some cases they were just buttoned. These men stood or laid in a shallow trench for 30 - 60 minutes downwind of a contaminated (usually 100 g/m² of H) area of ground. The clothing was worn for 4 hours from the time of commencement of exposure. It was then removed and a hot bath taken, the hands, face and neck decontaminated with ointment, Losantin or bleach paste.

Sometimes the men were exposed to vesicant vapour in a gas chamber, the same routine being observed.

(5) Aircraft Spray Trials

Clothing (impregnated and unimpregnated) was laid on the ground at various distances downwind. Only the left-sleeve of the jacket was exposed to the spray. After the spraying the jackets were worn for four hours by men. Guinea-pigs, with shaved bellies, clothed and bare, were also exposed at the same points.

(6) Anti-Tank Trials

(a) HCN bottle-grenades:- These were thrown against the turret of the tank. Caged cats were placed in the driver's seat, commander's position in the turret and on the gunner's seat.

(b) Harassing Agents:- The engine of the tank was removed and the ventilation arranged to simulate the ordinary rate of ventilation. The C.W. - shot was then fired against the tank. Immediately afterwards men, waiting behind moveable shelters, ran out and put their heads into the back of the tank by opening the two rear doors. The symptoms suffered were noted.

(7) CN Tests:- These were usually done in woods. After functioning of the munitions, human subjects entered the area to see how long they could remain there without adjusting their respirators. No objective tests of harassment were made.

(8) Sternutators:- Chamber tests were performed at Spandau, 0.5 mg/m³ being the standard concentrations.

In the field, volunteer officers and workmen on the staff stood downwind of sternutators smoke candles, and stayed there, without respirators, if possible for 2 or 3 minutes. Afterwards the symptoms they had suffered were told to the assessor. No objective methods of assessment were used.

(9) A Wind Tunnel for testing smoke candles etc. had only recently been made at Raubkammer. It had never been used.

(10) Animals in the field:- Dogs, cats, guinea pigs and mice were used chiefly. They considered dogs a good animal. Cats developed a gastro-enteritis sometimes fatal if kept in captivity for as long as four weeks. They were also sensitive to cold in the field, and, therefore, attempts were made to acclimatise them before hand by keeping them in large open cages. They were then placed in warm horse boxes after the trials. Guinea-pigs often died from cold and mice were especially susceptible.

(11) Inhalation Experiments were performed at Spandau in 1.5, 2, 10, 100 and 300 m³ chambers. The floor, ceiling and upper and lower thirds of each wall of the chambers were of glazed tiles, the middle third of the walls being of glass for observation purposes. Animals were placed in cages on stands in the chamber. Chemical sampling was performed by drawing the vapour out through holes in the glass portion of one of the walls. The agents were dispersed through another hole in the glass portion of the same wall.

(12) To test respirator filters against HCN or ONCl in the field, cats were exposed in cages which were protected by a respirator filter, through which air was drawn continuously.

(13) Comment: The Germans placed great reliance on animal tests and chemical sampling methods had to be correlated with toxicological observations before being generally accepted.

In general they showed an unrealistic approach to their field assessments. Thus

(a) Men were not directly exposed to aircraft spray. The methods they did use we know to be open to gross errors.

(b) No objective tests were used in assessing harassing agents. We know how misleading subjective observations can be in this case.

(c) Again men were not placed inside towed tanks for trials with harassing agents.

3. Mustard Gas and other vesicants

A. Mustard Gas

The work with human volunteers was done at the Military Academy, Berlin, by Colonel Welde and Captain Kroeber and at Spandau. Decontamination tests with ointment were done at the Military Academy. The human work was stated in 1936 and before that animals were used for vesicancy tests.

The Germans were aware that the genitals and armpits are the most sensitive areas of the skin and hence, for field work, designed rubber pants for protection.

The vesicancy of many different agents had been compared using the skin of guinea pigs, pigs and humans and the following descending order of potency has been found :-

H ..
H/Arsinol
H/HN-3 50/50
H/HN-3 35/65
HN-3

The delay in healing of the lesions followed the same order.

T (which the Germans called "T-ether") dissolved in H was considered to be a good vesicant. The size of the lesion produced by T was usually greater than with pure H. (Pure T was never actually used but usually a 90/10 T/H mixture). This was assumed to be because the T spreads more rapidly over the skin and so the lesions were not so deep and healed quicker. A 50/50 H/T mixture was suggested as being the best for vesicant power. The fact that T persisted for a long time on the ground - much longer than the German thickened H - had also been noted.

In all respects H-mixtures, such as OM, OA, OR, etc., were less effective than pure H.

Details of tests (18.1.44.) to compare the vesicancy of D (chlorschwefel-Lost) and O (Oxol-Lost) are available. The following results were obtained :-

(a) The ear of a rabbit - skin damage commenced at the same time. D produced a larger area of damage but a rather smaller blister. The lesions heal in the same time.

(b) On human skin - the effect begins a little later with D. The erythema produced by D is smaller but of equal intensity. The blister formation is later with D and not so extensive. The total extent of damage produced by D is much less than that produced by O.

(c) Shorn Horse skin - Pure distilled D and technical O have a similar effect but technical D is much less effective. (Flury obtained a similar result in 1928).

Hence O and D differ very little quantitatively in their action on the skin, but, with D, the action commences later and does not last as long.

For decontamination of the skin washing with soap and water was considered to be the best method especially if carried out within a few minutes of contamination. British A/G Ointment No. 5 and the American No. 5 Ointment were also thought to be excellent decontaminants. In addition the Germans considered that these ointments give excellent protection against H vapour. In fact, the "jelly type" of ointment, such as M5, was considered to be better than any equipment or impregnation yet devised for protection against H vapour. The Germans themselves would have liked to make an Ointment like M5 but were short of the necessary thickening agents.

It was considered extremely difficult to decontaminate all the body with an ointment, and so, for this reason, a decontaminating soap was introduced. M.S. Soap (Mersol) made by I.G. Farben was the soap finally chosen and, as is known, issued to the Army. It was intended for use by medical officers, decontaminating troops, and at decontaminating centres. They claimed that it is good against all vesicants, and was effective against H even 10 minutes after contamination. Dr. Postel did the original decontamination experiments at Spandau on guinea-pig skin and using 1-10 mg. of vesicant per 5 cm² of skin.

Some work had been done before the war by Dr. Oswald at Wurzburg on the possibility of obtaining a readily available decontaminant for H. Various ashes, mixed with water to make a paste, were tested on rabbits ears using a contamination of 5 mg. of H. The paste was applied thickly, left on for 5 minutes and then washed off. Coal ash was found to be no good, but wood ash, peat ash, lignite, etc., were effective. The control decontamination was done with bleach paste or by washing with soap or soft soap. The ashes were better than the soaps but not as good as bleach paste.

The following table gives the German figures for the relationship between contamination density and effect :-

Degree of Contamination in g/m ² of H	Bare or clothed Skin	Effect
0.1	Bare	Erythema
0.5	Bare	Erythema and Swelling
1.0	Bare	Vesication
5.0	Clothed	Nil.
> 5.0	Clothed	Vesication

Hence for offensive purposes (spray) it was estimated that a contamination of the order of 1 g/m^2 would be required to produce casualties on unclothed men, and for clothed men 5 g/m^2 would be needed.

No account was taken of drop size but it was predicted that the larger the drop size the greater the effectiveness since smaller drops were difficult to aim and readily evaporated. Therefore the thickening of H for anti-personnel spraying was recommended :-

Foreign spray mixtures were said to be :-

England - OB or HT - T 47.4 per cent.
H 25.5 per cent.

U.S.A. - 50 per cent H
15 per cent - H sulphone
10 per cent - brom H
25 per cent - Lewisite

Russia - 21 per cent - H
50 per cent - Lewisite
29 per cent - Intermediate products and impurities.

The American spray mixture seemed to have caused them considerable trouble in making, but they did, at least, vesicant tests with it as the following Spandau results show :-

Time	Effects produced by 3 mg H on the skin.	Effects produced by 3 mg USA mixture on the skin.
3 hrs.	Reddening commences	Reddening commences
1 day	Beginning of blister formation.	Reddening and swelling
9 days	Ulcer and slough	Ulcer and slough
55 days	Healed. Scar.	Healed. Scar.

No German figures for the effects of H vapour on man are available. They seem to have relied entirely on Italian data as these were quoted many times in their papers. These figures are as follows :-

Dosage in mg.min/m^3	Condition of Skin.	Result on Skin
1000	Dry	Erythema and swelling
800	Dry	Nil
1000	Sweating	Vesication
250	Sweating	Erythema and swelling
< 250	Sweating	Nil

The only vapour tests done on human subjects at Spandau were those in which the forearm, covered by a rubber glove, in which a window 5 cm square was cut, was exposed to a stream of vapour in a glass tube. The forearm was inserted through a close fitting rubber ring at the end of the tube. Concentrations of about 400 mg/m³ of H vapour were used and exposure times varied between 5 to 30 minutes. A ct of 8-10,000 mg min/m³ was said to only produce an erythema. Vesications were never seen. Great individual variations in sensitivity to H vapour and the fact that sweating increased the skin sensitivity were noted during these experiments.

Toxicity of H

(a) By skin application - There was not much interest in this and only a few tests were made.

The following MLD's are noted

Cat (back contaminated) 30 mg/Hg

Guinea pig (belly contaminated) 20, - 25 mg/Hg

Rabbit 20 - 40 mg/Hg

(b) By Inhalation - here again the data are scanty although details of toxicity experiments with D and O are available.

<u>Substance</u>	<u>Concentration</u> <u>in mg/m³</u>	<u>Time</u> <u>in</u> <u>Mins</u>	<u>Ct in</u> <u>mg. min/</u> <u>m³</u>	<u>Animal</u>	<u>Deaths</u>
Pure distilled D 99.4 per cent.	39.6	30	1190	<u>Cat</u> <u>Mouse</u>	<u>2/5</u> <u>14/20</u>
Pure distilled 99.5 per cent.	38.64	30	1160	<u>Cat</u> <u>Mouse</u>	<u>1/5</u> <u>4/20</u>
Technical D 82.4 per cent	35.71	30	1170	<u>Cat</u> <u>Mouse</u>	<u>0/5</u> <u>4/20</u>
Technical O 89.6 per cent	35.26	30	1060	<u>Cat</u> <u>Mouse</u>	<u>2/5</u> <u>8/20</u>
D in benzene solution.	Nominal 50	30	Nominal 750	<u>Dog</u> <u>Cat</u> <u>Rabbit</u> <u>Guinea Pig</u> <u>Rat</u> <u>Mouse</u>	0/1 1/2 1/1 0/1 0/2 0/2

O in benzene solution	Nominal 50	30	Nominal 750	<u>Dog</u>	0/1
				<u>Cat</u>	0/2
				<u>Rabbit</u>	0/1
				<u>Guinea pig</u>	0/1
				<u>Rat</u>	2/2
				<u>Mouse</u>	2/2

(Note the habit when using nominal concentrations, of estimating the actual Ct by multiplying C/2 by t

From the above they conclude that, on inhalation

(1) Pure distilled D was slightly more effective than Pure O (99.5 per cent).

(2) Technical D (82.4 per cent) was slightly less effective than Technical O (89.6 per cent).

(3) D in benzene solution was slightly less effective than O in solution.

(4) The L(Ct) 50 for pure distilled D (and O) was probably about 1200.

(5) Not enough animals were killed by the technical gas to estimate the L(Ct)50.

Spandau had noticed that Ct was not a constant for H vapour on inhalation, the smaller the t, the smaller was the Ct. Using exposure times of from 1 - 3 minutes & Ct of 750-1500 mg.min/m³ would kill most dogs and cats (Dr. Bottger, Spandau). It was believed that the L(Ct)50 for man would not be greater than 2,000 mg.min/m³ because all other species tested showed a L(Ct)50 of less than 2000 mg.min/m³.

Pathology

This was not done at Raubkammer except on animals killed in field trials. In general, their findings confirmed those of Allied workers. Cats and dogs, dying from inhalation of H vapour in field trials, showed a pseudo-membranous tracheitis and bronchitis and broncho-pneumonia. Conjunctivitis and oedema of the eyelids were also seen and the guinea pigs, used in assessing vesicancy, showed oedema and necrosis of the skin.

Signs of gastro intestinal damage were only noted where animals licked the contaminated fur or in feeding tests with contaminated food. Oedema and Haemorrhagic necrosis of the gut and even stenosis of the cardiac end of the stomach with ulceration of the mucosa is seen.

Only in these animals was diarrhoea noticed.

The bone marrow did not appear to have been examined.

Specimens illustrating the above points of interest were seen at Raubkammer.

Therapy

The German methods of treatment patients suffering from mustard burns was as follows :-

- (1) Calamine lotion. This was later in short supply.
- (2) Potassium Permanganate solution 1/3,000 - 1/5,000.
- (3) Boric acid solution.
- (4) "Rivanol" (Bayer; 2 ethoxy - 6,9 - diaminoacridinolactate) dressing.

Blisters were evacuated of fluid and the roof collapsed down onto the burn area before dressings were applied.

Systemic

In severe cases (12 in one accident with H/Arsinol["] in 1941, when this observation was first made) an aleukoemic leucopenia had been noted in humans. This had not been noted by the Germans before this accident. It was confirmed in later accident cases. Dr. Postel did the haematology on these and subsequent cases. Because of his "original" work he was commended and ordered to Berlin, to continue his research under Colonel Welde, at the Military Academy.

Sternal punctures were made on the cases and few leucocytes were found. The "young immature" Leucocytes were chiefly missing.

This leucopenia was treated with whole blood transfusions, the amount of blood given varying with the severity of the case. On an average 400 cc. of blood were given at a time (maximum 600 cc) and repeated if necessary. One case had 10 transfusions in all.

Eight of the first series of 12 cases died, but many with very low white cell blood counts have recovered under treatment, e.g. one girl had only 800 W.B.C./mm³ but recovered.

For the first day or two after the accident a few patients showed the symptoms of "shock" which was considered to be due to the H absorbed rather than the burns; the "shock" picture was not as pronounced as with thermal burns of equal extent and intensity.

There was no evidence of Haemocentration but many cases showed a later polycythaemic because of the number of blood transfusions received.

Pentamucleotide was tried for the leucopenia but without effect. Good food and oxygen (in the early stages) to unconscious cases and cases suffering from respiratory distress were also given.

The cases which died were autopsied by a pathologist from Berlin who removed the organs and took them back to Berling. The microscopic findings on these organs were not known to the local Medical Officer. Microscopically, however, many cases showed a tracheitis and bronchitis with gross pseudo-membrane formation and broncho-pneumonia (Some of the cases which recovered also had a membranous tracheitis and often coughed up large pieces of membrane). No gross changes in the intestinal canal were remarked upon, though one case, who swallowed some liquid H, actually had a perforation of the stomach. The bone marrow does not appear to have been examined at autopsy.

None of the cases suffered from vomiting or diarrhoea.

No specified therapy for H had yet been discovered.

The best method of decontamination in the factory was soap and water washing, supplemented in many instances by bleach, Losantin or even carbon tetrachloride. These methods were only effective if applied within the first few minutes after contamination. A 2 per cent chloramine solution was used to decontaminate clothing.

Theories of the mode of action of H

Work done by Long and Wirth at the Military Academy in Berlin and by Flury suggested that H inhibited cell enzymes. Hence the oxidation of cell was interfered with and this was followed by death of the cell. The enzymes studies were not known to our informants.

Offensive Use of H

Two types of munitions were envisaged - those to produce a vapour hazard and those for ground contamination. On the ground un-thickened H persists as a hazard for 1 to 2 days, but, under favourable conditions, thickened H may persist for 2 or 3 months.

It is estimated that to produce an effective traversing hazard a minimum contamination density of 100 g/m² would be required.

However, the production of such a hazard would be of doubtful value and no trials to assess the hazard were performed. Occupying hazard was also never assessed.

For anti-invasion purposes trials were done to assess the hazard presented by H floating on water. Pieces of cloth were dipped in the floating H, then placed onto guinea-pigs' bellies and the resulting burns assessed. The requirement was to provide a mustard gas hazard from floating H for two hours. H as a foam or absorbed on Fuller's Earth was tried but without success.

B. Other Vesicants

Not much work was done on these.

(1) No success was achieved with unsaturated H Compounds.

(2) HN3 was considered to be less vexicant than H and readily decontaminated with soap and water. It was charged into shells and not bombs and was used to produce an inhalation and not a contamination hazard.

(3) HN2 was considered too unstable.

(4) Little work has been done with Lewisite. BAL Ointment has been tested and was considered excellent for decontamination of both the eyes and the skin.

(5) Bromo-H and iodo-H were tested for vesicancy on animals at Spandau. Bromo-H equalled H in vesicant power but iodo-H was not as good as was less stable.

(6) Impregnated Dusts - Test with H, HN3 and HT absorbed onto Fuller's Earth, Kieselguhr, etc., had been made at Spandau. The French reported that such dusts were 10 times more efficient than the pure vesicant. Only a few tests were done by the Germans, the impregnated dusts being blown down a tube onto animals and mens forearms. All had the same qualitative effect as pure H and were at least equal to pure H in potency. Particle sizes varied from 1 - 10 μ the smaller particles being the more effective. The concentration was estimated from the rate of sedimentation of the particles. (An attempt was also made to apply Tabun to dust, but without success. Tabun was too readily hydrolised).

C. Impregnated Clothing

The possibility of protecting against H vapour by means of impregnated clothing and anti-gas ointments was under consideration.

They knew of the British and American impregnates E and CC-2 respectively and they had made several similar compounds for trial themselves, e.g.

Selloxin 1 N-chlor-benzoic acid 2:4 dichloranilide.

Selloxin 3 N-chlor-benzene sulphonic acid 2:4 dichloranilide.

Selloxin 5 N-chlor-acetyl 2:4 dichloranilide.

It was known that some of these impregnates could produce methaemoglobinaemia and toxic effects by skin absorption, e.g. Selloxin 5 produced up to 38 per cent methaemoglobinaemia and 3 mg/kg produced death in animals (rats, cats and guinea-pigs) on subcutaneous injection. Cats have shown methaemoglobinaemia varying between 5 and 60 per cent.

To decrease the sensitivity to water higher fatty acid derivatives of Selloxine were tried and with some success. Thus Selloxin 2011 (N-chlorinated 2:4 - dichloranilide of Stearic acid) with 15.3 per cent active chlorine was the best and was non-toxic to animals in doses of 3 mg/kg.

However, the raw materials to make this compound or other aniline derivatives were lacking and so melamin, $N_3C_3(NH_2)_3$ derivatives were studied, e.g.

Selloxin 50 - Trichlormelamin

Selloxin 51 - Hexachlormelamin

Selloxin 52 - Dichlormelamin

Various routine physiological tests were made with clothing impregnated with these materials. This routine is given below and illustrates well the methods used in assessing this kind of protection :-

(1) Chemical penetration times - compared with impregnated clothing.

(2) Laboratory trials with human subjects. The forearms were covered with a rubber sleeve with a window into which clothing is placed. These cloth windows were exposed to H vapour. (1290 mg.min/m³ at 29°C.).

(3) Field trials using human subjects wearing impregnated and unimpregnated trousers and jacket and standing downwind of contaminated ground (100 g/m² of H or H/Arsin⁸l. Chemical estimations of the vapour hazard were made.

(4) Because of the poor vapour returns, these trials were repeated in a warmer climate (Wasilika and Litra Sedes in Salonika, Greece). Various methods of impregnation, e.g. soaked or sprayed with Selloxin 52, new and old (3 weeks wear) uniforms, and unimpregnated new and old uniforms were used.

Because of the absence of vapour effects a second trial using two half-hour periods of exposure, the ground contamination being refreshed between these periods, was tried and again no effects were produced and so the contamination density was doubled and an hours exposure tried. This time skin reactions were obtained, the erythema often not appearing for 1 to 2 days and not for 3 or 4 days in some cases.

The results of these trials may be summarized as follows :-

- (1) Selloxin impregnated clothing was no better than unimpregnated clothing. In fact, on the whole, unimpregnated clothing was better than impregnated clothing.
- (2) Buttoned sleeves were better than bound sleeves.
- (3) Used clothing was better than new clothing.
- (4) Anti-gas ointment was better than cod liver oil, which in turn was better than vaseline.
- (5) CC-2 impregnated clothing, 2 per cent Selloxin (bucket aqueous impregnation) and 6 per cent Selloxin were also compared in a trial where five areas (18 m. x 50 m) with 20 m. between were contaminated with H/Arsenol. The subjects laid in a shallow trench for two hours and at 25 m. downwind of the contamination. Sleeves and necks of the jackets were buttoned and ointment rubbed onto the hands. The uniforms were worn for a further two hours and then a hot bath was taken. Guinea-pigs were used as controls to test the vesicant power of the vapour.

The results were poor since the vapour concentrations were not great enough and it was decided that effective H vapour concentrations could not be obtained at Raubkammer.

- (6) Trials in the 300 m³ chamber at Spandau were therefore commenced. CC-2, Selloxin 52, and Selloxin 13 (composition unknown) - impregnated clothing was tested. The protection afforded by the Selloxin 52 clothing seemed to have been small. Selloxin 13 clothing may have been better but no unimpregnated clothing was used as a control and in this test, too, the Ct was lower.

(7) Trials at the Institute of Pharmacology and War-Toxicology of the Military Academy indicated that Selloxin clothing gave protection against fine drops of H. Therefore aircraft spray trials on impregnated clothing, the left sleeve of the jacket only being exposed to spray, were performed. The impregnation was a 6 per cent watery solution of Selloxin 52 and this was effective in protecting against 5 - 7 g/m² of H/Arsenol. (Any skin changes which did occur through the impregnated clothing were explained on the ground of faulty and uneven impregnation). This trial is described in detail in Section XI.

(8) Laboratory trials, in which the left sleeves of worn field jackets, (impregnated with 4 or 6 per cent Selloxin 52) were contaminated with H (120 mg/120 cm²) and subsequently worn for 4 hours, indicated that such impregnation did not protect against 10 g/m² of H.

These results with impregnated clothing were considered by the Germans themselves to be particularly poor; if such poor protection were obtained under the artificial conditions of these trials, then the results in the field would be much worse. The difference between the poor field trials and the good laboratory results was explained on the following grounds :-

(1) The "climate" under the uniform was different from that of the surrounding atmosphere. It was warmer and more moist, and hence the skin was more sensitive. This warmth and moisture is supposed to be greater under impregnated than under non-impregnated clothing, under new than under old, and under bound than buttoned sleeves.

(2) There was also a "pump-effect" which draws vapour under, rather than through the clothing so that the skin could never be completely sealed off from the surrounding atmosphere. This "pump-effect" was said to be more marked with German than with Allied uniforms.

In conclusion it may be said that the German-type uniform was not suitable for impregnation against H vapour. In 1945 a uniform designed like the British battle-dress was to have been produced. Impregnation of this may have been more successful. Impregnated German uniforms offered a greater degree of protection against H spray than they did to H vapour.

4. Phosgene Oxime (Kanton)

Work on Phosgene oxime was commenced because it was believed that the Russians would use this agent. It was intended to contaminate ground, skin and clothing. The compound was examined at Spandau on the skin of men and animals. The results were as follows :-

- (1) Minimum amount in benzene solution required to damage 1 cm² of skin was 0.2 mg.
- (2) In the solid or crystalline state 0.1 mg. was effective.
- (3) Kanton/H mixtures were reported to have been found in Russia. Various concentrations of Kanton in H were assessed at Spandau. A fresh Kanton/H mixture was found to be the best. The mixture (5 mg.) produced the same effects in the same time as pure H (5 mg.) but the lesions healed 2 - 4 weeks sooner than the pure H lesions.
- (4) A 3 day old 40/60 mixture was less effective than pure H since Kanton hydrolyses rapidly. Healing occurred 8 days earlier in some cases.
- (5) Kanton was soluble to the extent of 33 per cent in H and in the 40/60 mixture it was suggested that only the undissolved Kanton was effective.
- (6) To penetrate uniform large amounts of Kanton were required, e.g. 100 mg. on a small area and, therefore, it did not compare with H in this respect.
- (7) Its real value was in the intense irritation and pain it produces within 1 or 2 minutes of coming into contact with the skin.
- (8) Kanton/H mixtures were poor from a military standpoint since both the irritating effects of Kanton and the vesicant power of H were reduced.

5. Phosgene and other lung irritants

No new lung irritants had been developed and the Germans were relying solely on Phosgene. A phosgene-cyanogen chloride mixture had been tried but it was not found to be effective.

At Spandau an attempt was made to get an exact L(Ct)50 for mice but without much success, as the mice had a high mortality themselves during the winter of the test. The results obtained did suggest a L(Ct)50 of 1000 to 1,500 mg.min/m³. Dogs and cats gave a similar L(Ct)50. Man was considered to react to phosgene in a manner very similar to that of dogs (Flury held the same view) and for this reason apes were not used for phosgene experiments. Spandau believed that the Ct for man is less than 3,000 mg.min/m³. On the other hand Sartori's figures for man were often quoted, e.g.

Concentration in mg/m ³	Time in Mins.	Ct in Mg.min/m ³	Effect.
10	10	100	Illness
40 - 50	10 - 30	400 - 1,500	Death

Experiments on therapy were done by Professor Wirth at Spandau and Colonel Welde at the Military Academy.

Dichlorodimethylether had also been studied at Spandau. Animals exposed to 100 mg/m^3 for 30 minutes died after 8 - 14 days from pulmonary damage though not specifically from pulmonary oedema. This was not considered a good agent and the work was stopped.

Two cc. of alcohol, ether, chloral hydrate or acetone given subcutaneously to rats before gassing with CG were without effect. Treatment of phosgenised rats with ozone increased the mortality.

6. HCN and CNCl

HCN

No estimate of the Ct for man had been made by Spandau. Flury's figures were the standard ones in use and these are :-

Man of average weight 70 kg. :-

Lethal dose 1.0 mg. of HCN/kg. body weight.

Vol. of air breathed in litres.	Time in Mins.	Concent- ration in mg/m^3	Ct mg. min/ m^3	Amount breathed in mg.	Dose in mg/m^3
20	0.5	3,500	1750	70	1.0
40	1.0	1,750			
60	1.5	1,167			
80	2.0	875			
100	2.5	700			
120	3.0	583.3			
140	3.5	500			
160	4.0	437.5			
180	4.5	389			
200	5.0	350			
220	5.5	318	2000	80	1.14
400	10.0	200			
1,200	30.0	150			
2,400	60.0	150			
2,400	60.0	50-60			
			3-3,600	120-140	1.7-2.1

Some further figures, source unknown, are appended :

Athletic Man 68 kg. Concentration HCN in mg./m ³	Breathing Time in minutes.	Rate 50 L./min. Effect.	Amount Absorbed in mg.
50-60	1	Nil	150-180
150	$\frac{1}{2}$ - 1	Death	225-450
200	1/6	Death	100
2000	Immediate	"pole-axed" death, can save with immediate artificial respiration.	

Some animal figures from Spandau were obtained :-

Species.	Effect.	Time in minutes.	Concentration in mg/m ³	Ct in mg.min/m ³
Cat	Convul- sions.	0.5	4-800	2-400
Cat	Death	0.5	1400-2000	700-1000
Guinea- Fig.	Convul- sions.	1-2		550-650 (approx.)
Guinea- Fig.	Death	1-2		1000-2000 (approx.)
Dogs	Were believed to be similar to cats.			

Cats

Concent- ration mg./m ³ .	Time in secs.	Ct in mg.min/m ³	Time after exposure in sec. for in- capacitation.	Lethal Ct.
2700	20	900	30	Survives
	25	1125	30	"
			45	1125
	30	1350	55	Survives
	35	1575	20	1575
			40	1575
2200	16	587	60	Survives
			60	"
	20	732.5	30	732.5
			60	Survives

Concentration mg./m ³	Time in secs.	Ct in mg.min/m ³	Time after exposure in sec. for in- capacitation.	Lethal Ct.
1000	20	333	45	Survives
	25	370	45	"
	30	500	35	"
680	60	680	50	Survives
			45	680
	80	906	60	906
	100	1131	65	1131
	140	1585	75	1585
300	90	450	90	Survives
	120	600	-	"
			120	600
	150	750	150	Survives
200	600	2000		2000
105	12-30 min.	1260- 3100		1260-3100
70	22-30 min.	1540- 2100		1540-2100
50	24-30 min.	12-1500		1200-1500
30	30 min.	900		Nil

With HCN the concentration in a gas chamber fell rapidly and hence a new method to stabilize the concentration was designed.

It was noticed that the greater the time of exposure the greater the Ct required to produce death.

Liquid HCN was found to be toxic on the skins of animals. The toxicity of HCN vapour through the skin had also been studied. This work was done because the German respirator was considered to offer excellent protection to HCN vapour, and so the hazard to HCN vapour by skin absorption was assessed. Two series of experiments were done - on humans and on animals.

In the human experiments four volunteer scientists each wearing a respirator or an oxygen mask and a bathing costume entered a gas chamber containing HCN vapour. Concentrations of between 1,000 to 4,000 mg/m³ were tried.

It was found that a Ct of 10,000 mg.min/m³ had no effect. Only one person became light-headed and had a transient feeling of nausea but did not vomit. These symptoms were considered to be of psychological origin. Higher CT's were not assessed because it was believed that such would not be obtainable in the field.

The animal experiments gave the following results :-

HCN by skin absorption :-

Species	Concentration in mg/m ³	Time in minutes.	Effect
Cat	5,380	120	Difficulty in breathing
	22,100	20	Death
	23,000	18	Death
Dog	5,300	58	Death
	5,300	62	Death
Pig	5,430	120	Difficulty in coughing
	12,800	85	Death
Guinea- Pig	910	1	} Reddening of the skin Reddening of the skin. Illness. Reddening of the skin. Illness.
	to 660	to 15	
	3,100 to	1-3 to	
	2,950	5-7	
	7,800 to	1-3 to	
	6,900	5-7	

Nothing new had been suggested as a therapy for HCN poisoning. Nor had the possibility of protection against HCN by the prophylactic production of methaemoglobinaemia been considered. Standard remedies were :-

(1) Artificial respiration.

(2) 10-20 cc. 3 per cent sodium nitrite intravenously. This formed cyan-methaemeoglobin and this effect was increased by the administration of insulin and decreased by the administration of glucose.

(3) Sodium thiosulphate (Flury) 50-70 cc. of a 50 per cent solution intravenously, giving 2.5 to 6 cc. per minute.

(4) Injections of methylene blue solutions containing :

Methylene blue	1.0
Glucose	25.0
Water	to 100.0

(5) Lobeline injections hypodermically to stimulate respiration. The above were tried in accidents which occurred at Spandau.

CNCl

Not much HCN was made and even less CNCl, but they were worried by the possible Russian use of CNCl.

However, CNCl was not considered to be a good war gas because

(1) It was a lachrymator and much better harassing agents were known.

(2) It was readily detectable and hence a surprise lethal effect would not be possible.

CNCl produces a marked and rapid inhibition of respiration so that breathing stopped immediately. This inhibition is a reflex mechanism through the vagus and was first seen in cat experiments done at the Military Academy and the Kaiser Wilhelm Institute in Berlin. In smaller concentrations the frequency and the respiratory volume are gradually reduced until respiration ceased. Because of this immediate respiratory inhibition produced by dosages approaching field concentration, a 60/40 HCN/CNCl mixture was not considered practical as in this mixture the effect of CNCl predominated.

Contrary to British and American opinion, it is considered that HCN produces a gradual depression of the respiration with no initial stimulation.

The opinion was expressed that the L(Ct)50 of CNCl might not be much more than that of HCN. Animal experiments using high concentrations give a wrong impression of the actual toxicity because of the inhibition of respiration which was caused. In fact it was suggested that here the longer the time of exposure the smaller the L(Ct)50, e.g. guinea-pigs had an L(Ct)50 of about 5,000 mg.min/m³ for short exposures and of about 2-3,000 mg.min/m³ for long exposures.

In testing respirator filters against CNCl, a concentration of 10,000 mg/m³ was used. This would usually pass through German filters in about 10 minutes. The desorption of CNCl from respirator charcoal was a well known phenomenon.

The following are some Spandau figures :-

CNCl - Cats

<u>Concentration mg/m³</u>	<u>Time in minutes</u>	<u>Lethal Ct. mg.min/m³</u>
30	30	No effect
60	30	1800
70	30	2100

<u>Concentration mg./m³</u>	<u>Time in minutes</u>	<u>Lethal Ct. mg.min/m³</u>
140	30	4200
280	11-30	31-8800
500	5-10	25-5000
4600	40-50	1840-2300

HCN-CNCl (60:40) Cats

<u>Concentration mg./m³</u>	<u>Time secs</u>	<u>Ct mg.min/m³</u>	<u>Onset of illness (secs.)</u>	<u>Lethal Ct. mg.min/m³</u>
5000	12	1000	23-25	1000
1250	36	750	30-50	Survives
1250	45	937.5	30-50	937.5 (25 per cent die).

7. Arsine and Aeroform

Aeroform is a mixture of magnesium and aluminium arsenides and was used in the form of a powder. It reacts quickly with the moisture in the air and on the ground to produce arsine in reputedly high concentrations.

The Spandau toxicity figures for arsine are tabulated below:

<u>Time.</u>	<u>Species - Cats.</u> <u>Concentration.</u>	<u>Ct mg.min/m³</u>	<u>AsH₃ retained when</u> <u>breathing at 40 L./min.</u>
33-50 hours.	10 mg/m ³	20-30,000	0.4 mg/min.
50 min.	200 mg./m ³	10,000	8.0 mg/min.
3 min.	1000 /m ³	3,000	40.0 mg/min.

The pathology and mode of action of arsine, as worked out by the Germans, resemble the British and American conceptions. Therapy was along conventional lines too.

The main value of arsine was considered to lie on the psychological effect of the presence of blood in the urine of affected troops.

Some experiments on the contamination of water with arsenical compounds had been done at the Military Academy, Berlin. Water contaminated with chlorovinylarsine or diphenylarsine up to a concentration of 1 mg./L. of water had no untoward effect on consumption. A contamination of 0.5 mg./L. of water was said to have absolutely no effect on humans.

It was also stated that, with a concentration of 2.6 g/m^3 , no arsine was retained in provisions. The same is true for Phosgene and Chloropicrin but against this was the fact that HCN is retained by certain provisions and they become poisonous.

Experiments with reducing and oxidising agents, and with sulphur-compounds in the treatment of Arsine poisoning were unsuccessful.

8. The Harassing Agents

CN was the only lachrymator in general use. (Possibly because the raw materials were lacking for the others or the factory space was limited). The Germans were not specially interested in lachrymators and no new compounds were studied.

The following were the Spandau "Harassing Concentrations" for CN:-

Detectable	0.025 mg./m^3
First signs of irritation	0.04 mg./m^3
Intolerable to the eyes	0.06 mg./m^3 for 10 minutes. 1.25 mg./m^3 for 30 minutes.
Intolerable to the skin	1000 mg./m^3 for 1 minute. 2000 mg./m^3 at once.

Bromomethylethylketone was the only other lachrymator for which any figures are available. Here the intolerable concentration to the skin was found to be $900\text{--}1000 \text{ mg./m}^3$ for one minute.

CN had been charged into the following munitions:

(a) The KC 250 bomb, airburst for use over wooded areas. The intention was to produce harassment and was only suggested for summer or tropical use.

(b) 20 and 30 mm. shot (charged solid CN and also CN in solution in chloroform) for attack against houses and barracks. This was not an accepted munition.

(c) 20 mm. A.P. shot for anti tank work. This was not an accepted munition.

Sternutators

The official harassing concentrations (Spandau and Sartori) were as follows.

Agent	Minimum Detectable Concentration in mg./m ³	Minimum Effective Concentration in mg./m ³	Intolerable Concentration for	
			2 min.	10 min.
Clark I	0.01	0.05-0.1	1.4-2.0	0.14
Clark II	0.004	0.02-0.1	0.6	0.06
Adamsite		0.1	1.5	
Dora		0.08	0.6	

Skin effects (Spandau)

Clark I : 700 mg./m³ produced no immediate effect but dermatitis might result if the skin were not washed after the exposure.

Clark II : 100 mg./m³ produced no effect.

The vanillamide-group of compounds had also been tested. Fifteen different compounds were assessed and of these capsaicin itself was considered to be the best. A concentration of 0.01 mg/m³ was found to be intolerable. Personnel working with these compounds became acclimatised to them. Manufacturing difficulties prevented a more extensive trial of these compounds.

EXCELSIOR, was considered by the Germans to be the most potent of the sternutators. It was difficult to make and must be pure to store. It had been tested in

- (a) Smoke-candles,
- (b) 20 and 30 mm. shot.
- (c) H.E. Chem. shell.

9. Phosphorus and fluorine compounds

A. Fluoroacetates

Full details of German work on compounds of the fluoroacetate type

are lacking but in general are closely similar to those obtained by Allied experimental stations. One possible major difference is that they considered ethyl -, and not methyl -, flumroacetate to be the most effective of these compounds. On the whole, they say, the more complicated the compound the less the toxicity.

The compounds were not irritating to breathe and produce no immediate symptoms. However, half to two hours later, clonic and tonic convulsions occurred and this was followed by collapse and later death. Intoxicated animals took some hours to die and this was said to be due to "cardiac embarrassment". Inhalation and ingestion experiments only were performed, and it was found that a concentration of 20 mg/m³ for 30 minutes was lethal for dogs and cats. Apes were not affected except in high concentrations, e.g. 400 mg/m³.

The different homologues that were tested all appeared to produce similar effects, merely varying in the dosage required. Flury has tried to find how these compounds produce their effects but without success. They are said to be very toxic when given by mouth. The lethal dosage by ingestion could not be obtained.

From a military point of view, these compounds were not considered to be important.

B. Phosphorus compounds

Three new compounds had been seriously considered as C.W. possibilities. They are :

- (a) TABUN, (Neuer Grunkreuzstoff, Gelan I, or Trilon 83)
- (b) SARIN, (Verbesserter Grunkreuzstoff, Gelan III, or Trilon 46).
- (c) SOMAN, (Pinakolin Grunkreuzstoff)

Many similar compounds had been tested, the chief of these probably being the ethyl homologue of Tabun (Gelan II, or Trilon 32).

All these compounds possess similar pharmacological properties though they differ widely in toxicity. They were considered to be parasympathetic stimulants or inhibitors of choline esterase.

In sufficient dosage they caused marked contraction of the pupils, bronchospasm with respiratory distress, diarrhoea, convulsions, unconsciousness and finally death. These clinical features had been noted in animals (all three compounds) and in men poisoned as the result of accidents with Tabun and Sarin.

Toxicity

The toxicities of these compounds were estimated at the Military Academy in Berlin. Some of these figures have been found.

They are reproduced below :

(a) Tabun.

<u>Concentration in mg./m³</u>	<u>Ape</u>	<u>L(Ct)50 for Dog in mg.min/m³</u>	<u>Cat</u>
10	900	900	620-900
13-16	720	180-670	400-480
30	600	400-900	400-900
70	400	600	700
150	150		150-450

It will be seen that the greater the concentration the smaller the L(Ct)50. The pigeon was said to be the most sensitive animal, the L(Ct)50 being about half that of other animals. In order to get stable concentrations and therefore reliable toxicity figures they stressed the importance of using short exposure times, such as 0.5 to 3.0 minutes.

A few experiments were done with Tabun on its toxicity by skin absorption. They found that 100 mg. on the shaved back of a dog would cause convulsions but not death.

(b) Sarin.

(1) Subcutaneous injection of an aqueous solution into dogs:

LD50 ----- 0.02 mg.kg.

Amount to produce ataxia ----- 0.01 mg./kg.

(2)

<u>Species</u>	<u>L(Ct)50 in mg.min/m³ with conc. of 25 mg/m³</u>	<u>on inhalation. with conc. of 10 mg/m³</u>
Dog	59	67
Cat	89.5	135
	25	27.5
Mouse	227	--
Rat	137-177	--
Rabbit	227	
Pigeon	25	

The above concentrations for Sarin are nominal. No chemical estimations were made, but the actual concentration was estimated to be half the nominal. Hence the Ct figures given are Nominal C/2 x t. mg.min/m³.

(c) Comparable Toxicities

No figures for Soman are available except those listed below

Agent.	Dog.	L(Ct)50 in mg. min/m ³ for Cat.	Ape.
Soman	15-20	50-60	50-75
Sarin	80-100	80-90	100-150
Tabun	250-300	150-200	>150

L(Ct)100			
Sarin	150-200	150-200	-
Tabun	350	250-300	-

(d) Tabun was known to be toxic when placed into the eye of an animal, and this fact had been used in assessing the potency of technical samples of Tabun. A 15 cmm. drop (corresponds to 20 mg. of pure material) is placed in the eye of a rabbit; the production of convulsions was considered to be satisfactory.

In the human eye, 0.5 gamma of either Tabun or Sarin will cause contraction of the pupil. It was also estimated that 1 mg./m³ for 0.5 minutes will cause miosis in 5-10 minutes.

Smell: Tabun has an ester like smell.

Sarin has no smell.

Soman has a smell like camphor.

Volatilities

The volatility of Tabun was similar to that of H₂, and so at normal temperatures it offered chiefly a liquid hazard in the field. However the vapour hazard increases with increasing temperature and increasing wind velocity, and it recommended chiefly for summer or tropical use. Soman and Sarin were said to be more volatile than Tabun but no accurate figures were available.

Human accident cases

The Medical Officer from Dyhernfurth was interviewed. Several severe accident cases with Tabun were treated. (One or two of these may have been due to HCN which is used in the process). All the workers wore full protective clothing and respirators, and the accidents were due to a stream of liquid Tabun striking them in the face and forcing itself between the face and the respirator. They became giddy, vomited, and so then removed their respirators, thus inhaling more of the gas.

On examination they were all unconscious (one or two were still excited but not conscious) had a feeble pulse, marked nasal discharge, contracted pupil, asthmatic type of breathing, and smelled strongly of flowers. Involuntary micturition and diarrhoea occurred. Cases of Sarin poisoning had occurred at Spandau, and there is the possibility that one case occurred at Raubkammer but the Medical Officer was not sure what the agent really was. This case represented the clinical picture of lung oedema when first seen. He was unconscious, had marked contraction of the pupils, but did not smell of flowers. This patient recovered after venesection, when 450 ccs. of blood was removed.

No cases of Soman poisoning were known to have occurred in humans.

Pathology

In the animals which died quickly there was little to be seen at autopsy. The animals which remained alive for a few hours after gassing petechial haemorrhages into the pons, medulla and cerebrum, with surrounding oedema, could be seen.

The human cases which died were autopsied by a Major Rost, from the Military Academy in Berlin. By the naked eye, the only abnormality was congestion of the lungs and brain. The organs were removed, samples of blood and serum obtained and these were taken back to Berling for detailed examination.

Therapy

This was worked out by Colonel Welde at the Military Academy, Berlin, and is as follows :

(1) Eyes: Liquor. Scopolamine Hydrobromide 0.1-0.2 per cent drops into the eye. To prevent overdilatation of the pupils, tablets of cocaine hydrochloride 2.5-10 per cent are also inserted. In marked cases Syntropan (Roche) was used in 2 per cent solution.

(2) Lungs: Codeine Phosph.

Tab. Ephedrine 0.05 mg.

(3) Severely Ill Cases

1 cc. B.S. solution (atropine sulphate in 0.01-0.02 mg. doses and Sympotal 0.12 mg) intramuscularly. Sympotal is a new drug manufactured by Boehringer Solen.

10-25 cc. of 25 per cent glucose solution four times in 48 hours.

In the early excited cases, light ether narcosis.

For more severe cases, 5-10 cc. of sodium evipan intramuscularly.

With cyanosis and respiratory distress, oxygen and artificial respiration.

The above drugs were put up into First-aid Boxes for even the ordinary workman to use.

Cardiac stimulants such as Cardiazol or Camphor, are contraindicated.

Even after the acute symptoms have passed, the cases need careful nursing and observation.

In the human accident cases discussed above, B.S. solution was injected intramuscularly at once. (In the most severe cases it was given intravenously, although no instructions to do so had been issued). Sympotal and Strophanthin were given for the heart, and artificial respiration, cardiac massage and oxygen by mask where necessary. Two of these seven cases recovered even although they were unconscious when first seen. Upon recovering consciousness, they became excited, had "minor convulsions" and micturated involuntarily. They were therefore narcotised with sodium evipan and were quite normal again when awaking in 8 - 10 hours time.

Decontamination of these patients was performed with sodium bicarbonate solution.

Offensive use:

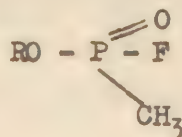
Details of the trials done with Tabun and Sarin are given in Section X. It was, apparently, intended to use these agents as lethal gases, the harassment caused by the contraction of the pupil being considered to be of only minor importance. For Tabun they aimed at a concentration of 100-200 mg./m³ but they could not always rely on getting this. Tabun was not as good as HCN against tanks because it was not quick enough in action.

Future Work

An attempt was made to replace the phosphorus of Sarin with arsenic as it was thought that this would be a very effective compound. No success had so far been achieved.

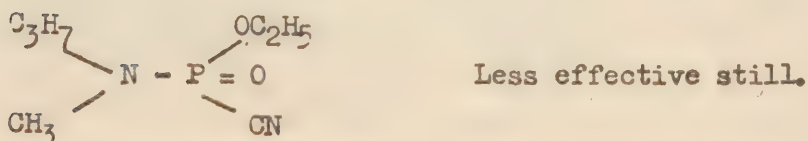
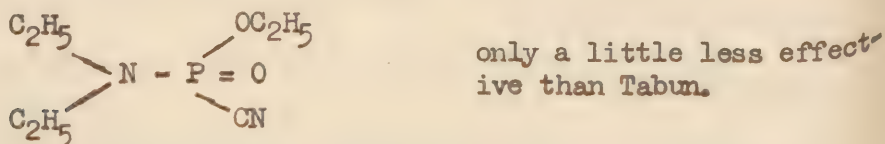
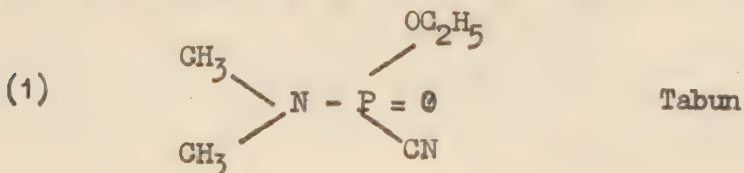
Dr. Böttger had been moved recently from VIII to VbL in order to study the action of organic phosphorus compounds on the vegetative nervous system. It was hoped to discover the mechanism of action and thence a rational therapy. Active work on this project had not yet started.

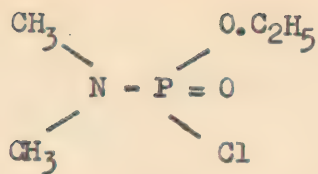
About 50 compounds of the Sarin-Soman type had been tested for toxicity. From these tests, apparently, secondary alcohols are best, i.e. compounds of the general type



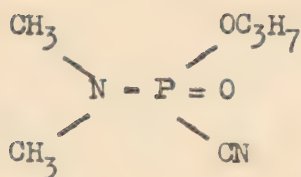
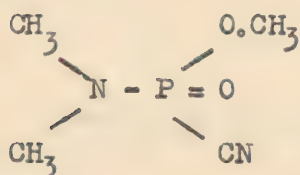
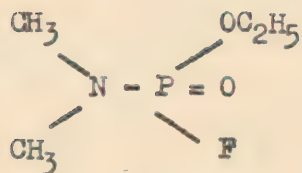
All compounds with 5 or 6 carbon atoms in the secondary alcohol group were good. R radicles with side chains gave good compounds; long straight chains were not very effective. Replacement of the methyl group in Sarin by ethyl, propyl etc., decreases the activity.

The following scheme illustrates the variation of toxicity with chemical constitution in this group of compounds.

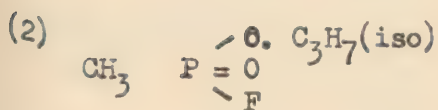
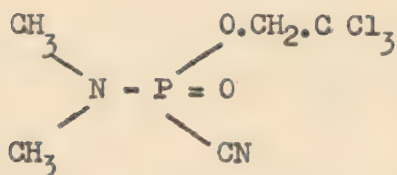




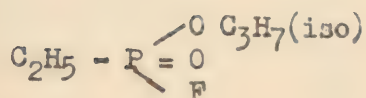
Ineffective



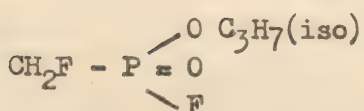
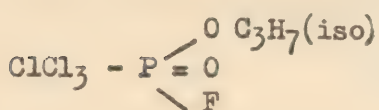
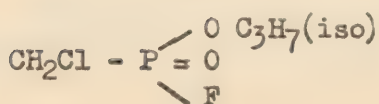
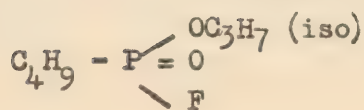
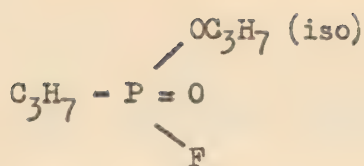
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Sarin .

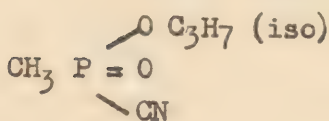
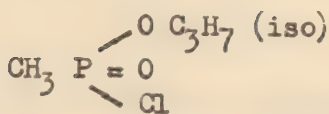
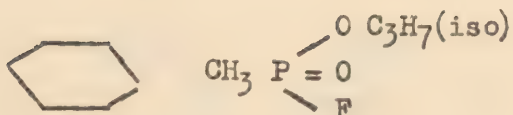
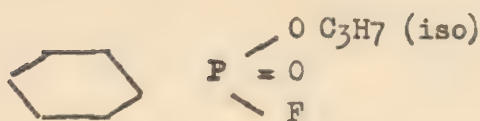


good but somewhat weaker than Sarin.

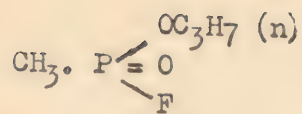


Much weaker than Sarin.

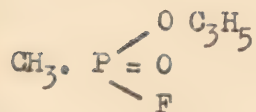
Almost without effect.



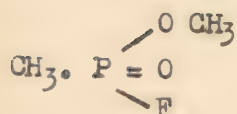
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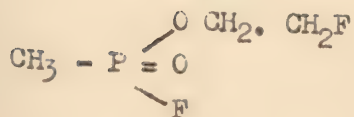
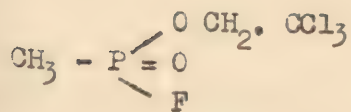
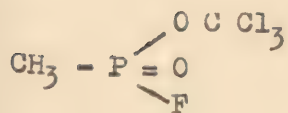
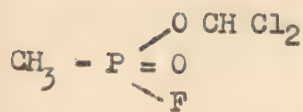
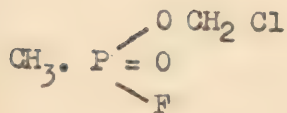
good but weaker than Sarin.



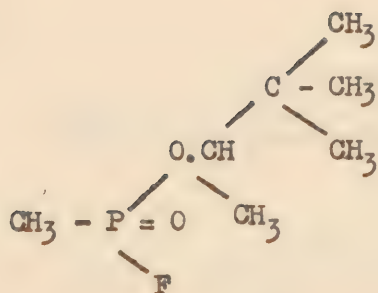
much weaker than Sarin.



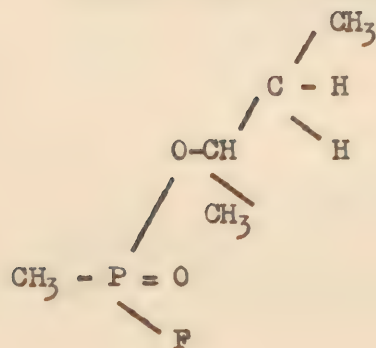
almost without effect.



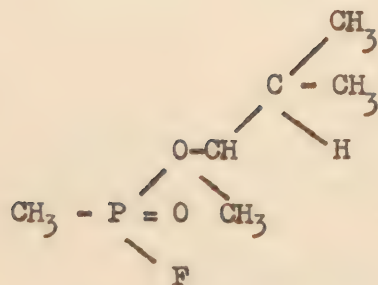
(3)



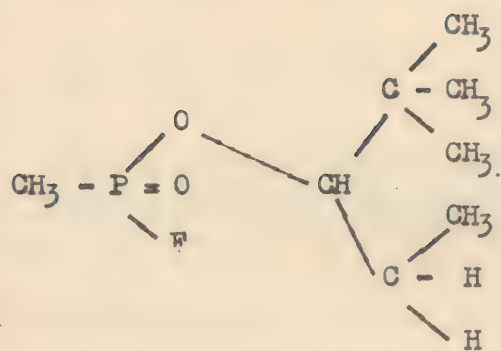
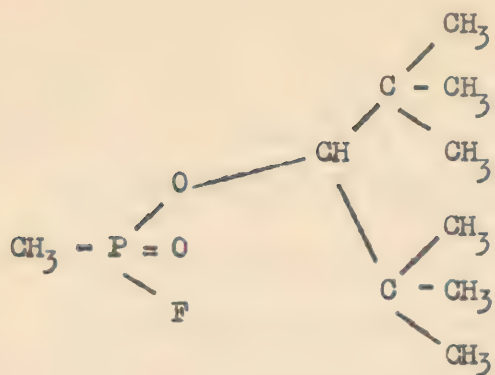
Soman. (The best of all)



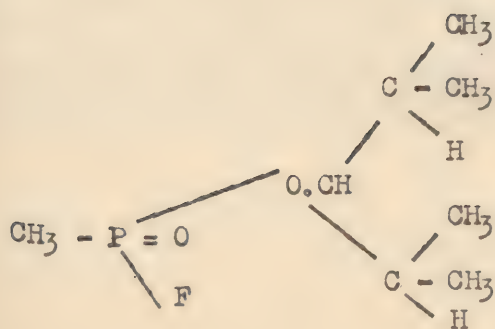
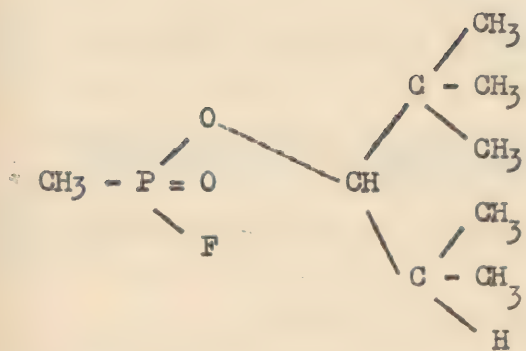
Better than Sarin.

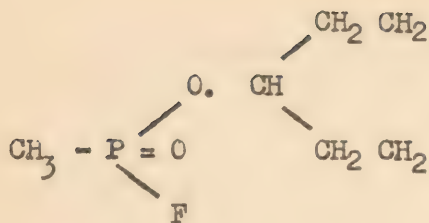


Good but not as good as Sarin.

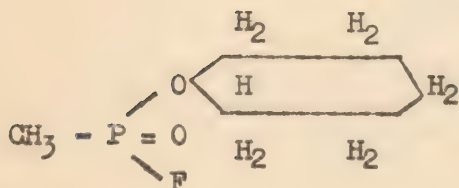


Not as good as Sarin.

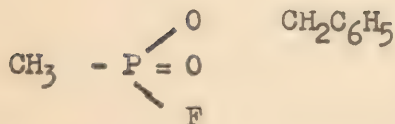




The next best to Soman.



Not quite as good as Sarin.



Ineffective - as are all the compounds containing aromatic alcohols.

It is interesting to note that the two optical isomers of the iso-amyl homologue of the Sarin type were equally toxic.

The allyl - Sarin homologue had a toxicity greater than Tabun but less than Sarin.

They were going to prepare Soman derivatives of alcohols containing 5, 6 or 7 carbon atoms, which they knew they could produce technically.

(The derivative prepared from a technical mixture of hexyl alcohols was ineffective).

Halogenation of these compounds rendered them non-toxic.

It is important to remember that, in assessing the relative toxicity by inhalation of these compounds, the various species showed a great variation in response to different compounds. The toxicity by subcutaneous injection did not show such a great variation and the relative toxicities, so assessed, agreed with the relative toxicities by inhalation on apes.

Again, these compounds were said to act by inhibiting choline esterase, but the sensitivity of the choline esterase varied with different species. Thus Sarin and Soman inhibit rabbit serum choline esterase to an equal extent; with dog and human serum choline esterase, Soman was 2 - 3 times more effective than Sarin.

Therefore compounds were screened by

- (1) subcutaneous injection in mice,
- (2) inhibition of human serum choline esterase.

(The test was done by adding acetyl choline to serum and titrating for acid after various time intervals. Then acetyl choline was added to a serum/compound mixture and titration again made. Bromo-thymol blue was used as indicator).

Promising compounds were then assessed by inhalation on dogs and apes, using short exposure times.

The toxicities of Soman, Sorin etc. by mouth or percutaneously were just being estimated. No figures had yet been obtained. Accident cases, however, do suggest that these compounds were toxic by skin absorption.

10. The Physiological results of field trials performed at Raubkammer

Two files containing some details of the physiological results of field trials held at Raubkammer were obtained. The trials listed were 174 aircraft weapon trials and 109 ground weapon trials. The aircraft weapon trials covered the period from 1935 to the present, the ground weapons trials from November 1940 to the present.

Unfortunately no corresponding tabulation of chemical and physical results of these trials has been forthcoming. In addition the physiological data are often incomplete or not sufficiently detailed. Therefore a comprehensive appreciation of the Raubkammer trials cannot yet be made.

However they do indicate the type of G.W. agents in which the Germans were interested, the types of munitions they were developing and the relative order of effectiveness of these various agents and munitions.

In the physiological assessment of the trials, the Germans graded the effects produced on the animals as follows :-

- = no effect
- / = slight effect
- // = moderately severe effect
- /// = severe effect
- (/) = death

In addition some idea of the effectiveness of a munition was obtained by calculating what they called "Lethal Areas" and "Total Effective Areas", where the "Lethal Area" was the area over which death of animals was obtained, and the "Total Effective Area" was the area over which death or illness of the animals was obtained. (Dogs and cats were the chief animals used in assessing field trials, although in some cases guinea-pigs and mice were also exposed).

As many of their trials were performed with experimental munitions and various types of burster and various weights of charging were used, in interpreting their data we have expressed the effect produced in terms of the Lethal Area in m²/kg weight of agent used. We have considered only the Lethal Area and not, in addition, the "Total Effective Area" because, we believe, the extrapolation from animal to man can be made with greater certainty where death of the animal has been produced.

The meteorological observations made at Raubkammer during the field trials seem to have been very scanty so that any indications of the effect of various weather conditions on the effectiveness of the CW agents could only be tentative. Fortunately facilities were such that many field trials, using different chargings in the same type of munition or different bursters with the same charging etc, could be performed on the same day. Hence direct comparisons under similar meteorological conditions could be made.

A. Aircraft Weapon Trials

The following trials are known to have been performed :-

- 33 using Aeroform
- 38 using HCN or CNCl
- 44 using Phosgene
- 2 using H
- 52 using Tabun
- 1 using Sarin.

Bombs and clusters burst statically, bombs dropped ground burst, with an instantaneous fuze or with a delayed fuze, or air burst, bomb clusters dropped, spray-bombs or aircraft spray were the type of munitions assessed.

Each C.W. charging will be considered in turn.

Aeroform

(1) KC 250 burst statically.

(a) Temperature has little effect on the performance

e.g.

Temperature	Lethal Area in $m^2/kg.$
- 14°C	17
✓ 7.2°C	13
✓ 6.1°C	16

(b) For the small ranges of wind velocity and relative humidity studied, neither of these factors can be considered to affect the lethal area.

(c) The average lethal area for these trials was 19 $m^2/kg.$

(2) KC 250 dropped.

(a) ground burst a lethal area of 8 m^2/kg was obtained.

(b) air burst over woods a lethal area of 9 m^2/kg was obtained, e.g.

Weather			MUNITIONS.	Animals killed.	Lethal Area in $m^2/kg.$
Wind in m/sec	Temp. in °C.	Rel. Hum. per cent.			
2 - 5	11.9	58	1 - KC 250 II GR 2 kg. FpO_2 149 kg Aeroform	3/53 Cats 1/11 dogs Inhalation time 10 min.	8
0	11.3	100	2 - KC 250 II Gr 322 kg Aeroform Airburst over woods.	6/28 Dogs 0/2 cats Inhalation time 30 min.	9

(c) Trials at Kieler Förde with bombs burst on the water or over the water were relatively ineffective in producing animal deaths. These trials were designed to test the effectiveness of this munition in attacking ships or invasion forces.

(3) Released from the S 500 :-

One trial was done (68 kg aeroform) and no animals were affected at all.

One virtue of aeroform was that it was not detectable by smell in woods and when airburst over woods, even the explosive charge could not be detected.

HCN and CNCl

Cats and Dogs were used for these trials. The cloud of gas was allowed to pass over the animals and then they were immediately inspected. The maximum time of exposure was estimated to be 2 minutes.

(1) KC 250 bombs burst statically :-

(a) There was little difference in effectiveness between a 60/40 HCN/CNCl mixture and an 80/20 HCN/H₂O mixture e.g.

Weather			CHARGING.	Lethal Area in m ² /kg.	REMARKS
Wind in m/acc	Temp in °C.	Rel. Hum. per cent.			
1	-1	87	HCN/CNCl	>120	Trials performed same day.
0.9	-1	83	HCN/H ₂ O	135	

(b) A 80/20 HCN/H₂O mixture was more effective than a 60/40 HCN/H₂O mixture, the effectiveness being roughly proportional to the HCN content e.g.

Weather			Charging HCN/H ₂ O	Lethal Area in m ² /kg.	REMARKS
Wind m/sec.	Temp °C.	R.H.			
1.9	14.5	39	80/20	67	Trials performed same day.
3.1	15	37	60/40	47	

(c) A better performance was obtained under conditions of low temperature and high humidity e.g.

Weather			Charging HCN/H ₂ O	Lethal Area in m ² /kg.	REMARKS
Wind m/sec.	Temp. °C.	R.H. %			
0.9	-1	83	80/20	135	
1.9	14.5	39	80/20	67	

(d) This bomb was very effective when burst statically in a wood, a lethal area of 243 m²/kg being obtained.

(2) KC 250 bombs dropped :-

(a) Charged with a 60/40 HCN/CNCl mixture an average lethal area of 43 m²/kg was produced.

(b) One trial was done using HCN alone and a lethal area of > 115 m²/kg was obtained.

(c) With a 80/20 HCN/H₂O mixture the lethal area was 18 m²/kg.

(3) Spray from the S500 :-

(a) In the open a HCN/CNCl mixture produced no deaths.

(b) With pure HCN an average lethal area of 50 m²/kg was produced.

(c) Over woods pure HCN, HCN/CNCl mixture or pure CNCl were equally effective. These trials were carried out on the same day.

(4) In two further trials the chemical analytical figures are available but not the animal data.

Munition	Concentration in mg/m ³	Sampling time in seconds.	Distance down- wind in m.	Remarks
1 - KC 250 V Gr 62 kg HCN/CNCl.	22,700 7,400	60 600	30 30	In a wood.
4 - S 500 2 kg HCN per 1 m. of flight.	12,200	60	30	In a dell

(5) Other results were

Munition	Weight in kg. or HCN	Lethal Area in m	Density of HCN in g/m ²
Spray	194	10,000	19
	200	10,000	20
	400	16,500	15.75

(6) A few notes summarising results of other aircraft trials were found. They are reproduced below.

(a) Bombing in a wood:

22,700 mg/m³ at once, to 7400 mg/m³ in 10 minutes.

(b) Spraying from aircraft:

Wind 1 - 2 m/sec.

Temp. -10 to + 10°C.

Height 10 - 15 m.

Open flat land 3.9 g/m³ in from zero to zero + 1 min.

High wood 2.9 ----- + 1 to 2 + 2 min.

Medium Wood 12.2 ----- to 2 + 1 ---

Phosgene

Munition	Average Lethal Area in m ² /kg.	Remarks.
KC 250 functioned statically	41	The higher the temperature the greater the effectiveness.
KC 250 dropped	<8	Data incomplete.
KC 500 functioned statically	?	Data incomplete.
KC 500 dropped	69	

Munition	Average Lethal Area in m ² /kg.	Remarks.
KC 1000 dropped.	48	
KC 1800 functioned statically	5	Data incomplete.
KC 1800 dropped	?	Data incomplete.
S 500	?	

The chemical but not the animal results are available for two trials :-

Munition.	RESULTS			Remarks.
	Concentration mg/m ³	Time in seconds	Distance in m downwind	
4 - KC 250 II Gr 400 kg phosgene.	65,000	10	30	Performed to assess danger from allied bombing of Ger- many with Phosgene bombs.
1 - KC 1800 II Gr 750 kg Phosgene.	32,000	10	30	

Tabun

Munition	Average lethal area in m ² /kg.	Remarks
KC 250 functioned statically	38	Pure tabun was more effective than tabun mixed with 18% or 40% chlorobenzene.
KC 50 dropped	40	
KC 250 dropped	48	Mixed with 18% chlorobenzene gave 54 m ² /kg.
KC 250 airburst at 50-100 m.	40 { one trial }	Data for other trials in- complete.
A.B. 250 each with 10 K.B.	83	80% Tabun / 20% chloro- benzene used in these trials. Wind velocity had little effect on lethal area.
A.B. 500 each with 20 K.B.	81	
Spray Bomb Spray	120 113(one trial)	80/20 Tabun/chlorobenzene also used in these trials.

Chemical data are available from one other trial :-

Munition	RESULTS		
	Concentration (mg/m ³)	Time (secs)	Distance (m)
KC 250 III Gr 80 kg Tabun	231	60	30

Sarin

Chemical data, only, from one trial have been obtained :-

Munition	RESULTS		
	Concentration	Time	Distance
KC 250 IV Gr 80 Kg Sarin	252 mg/m ³	60 secs.	30 m.

Mustard Gas

The results of thred spray trials only are available.

How Functioned.	Met. Conditions.	Contamination.
S500 (350 Kg OA) 51.1 m. height. Across wind.	Wind 5.5 m/sec. Temp. - air 19.2°C. Temp. - air 19.0°C. 11.5.44 - Date of Trial.	50 - 425 m. long 8 g/m ² max. at 325 m. 3 maxima e.g. 4.5 g/m ² at 80 m. 5.4 g/m ² at 150 m. 8 g/m ² at 325 m.
S500 (350 Kg OA) 44 m. height Across wind	Wind 10 m/sec. Temp. - air 18.1°C. Temp. - ground 17.2°C. Date of trial 25.5.44.	1.2 g/m ² at 175 m. 1.37 g/m ² at 225 m. Average 0.2 g/m ² .
S500 (350 Kg O) 25 - 30 m height. Downwind over a house.	Wind 2.8 m/sec. Temp. - air 10.2°C. Temp. - ground 10.8°C. R.H. 84%.	Contamination not meas- ured. Vapour returns were 3.5 mg/m ³ upwind side of house. 11.2 mg/m ³ } downwind side 14.5 mg/m ² } of house.

Full details of a fourth spray trial carried out on 20.10.44. are available and are given in the table below.

In this trial the protection afforded by impregnated clothing was assessed. The aircraft flew across wind at a height of 50 m. and sprayed from one S 500, containing 350 kg OA thickened with 6.4% P III. Sampling was done at 25 m. intervals for a distance of 250 m. downwind. Glass bottles (for heavy contamination) and metal trays (for light contaminations) were used to trap the vesicant and so measure the contamination densities at different distances downwind. The left elbows of impregnated and unimpregnated uniform jacket were exposed to the spray and subsequently worn by men for 4 hours. Bare and clothed shaved bellies of guinea pigs were also exposed.

B. Ground Weapons Trials

The trials with the ground weapons were either done from the Vauzet - Turm or fired at full range on to the layout near Bunker - Mitte. In many cases, on the same day, several similar shoots against animal layouts were done using the same type of munition but with various chargings. Moreover the number of rounds fired often varied with the charging, and by these means a realistic appreciation of the effectiveness of each charging was readily obtained. The chargings studied in the series of trials at our disposal included :-

Tabun

Sarin

Gelan II

Phosgene

HCN and CNCl

HN3

Mustard Gas.

For ease of comparison many similar trials have been grouped together. As will be seen the results are consistent enough to justify this method of analysis.

In general 15 cm shell have been assessed. The trials in which a direct comparison of different agents have been made, will be considered first.

Vauzet) Turm Trials

(a) Phosgene, HCN / Sarin in 15 cm shell.

Phosgene		HCN		Sarin	
Shell fired	Animals killed.	Shell fired	Animals killed.	Shell fired	Animals killed.
10	2	10	1	3	4
10	4	10	4	3	5
10	6	10	3	3	5
30	12	30	8	9	14 total

It will be seen that Sarin, in 15 cm shell, was about three times more effective than phosgene and about six times more effective than HCN.

(b) Phosgene, HCN, Sarin and Tabun in 15 cm shell

Phosgene		HCN		Sarin		Tabun	
Shell fired	Animals killed.	Shell fired	Animals killed.	Shell fired	Animals killed.	Shell fired	Animals killed.
1	0	1	0	3	9	2	1
10	8	10	5	3	7	5	1
10	3	10	6	3	3	5	3
10	3	10	3	3	6	5	1
10	4	10	4	3	7	5	3
10	0	10	4	3	8	5	4
51	18	51	25	18	40	27	13

Again Sarin is the most effective charging, being 4 to 6 times more efficient than phosgene, HCN or Tabun.

(c) Tabun, Sarin and Gelan II in 15 cm shell.

Tabun		Sarin		Gelan II	
Shell fired	Animals killed.	Shell fired	Animals killed.	Shell fired	Animals killed.
3	8	3	16	3	16
5	3	5	21	5	10
3	8	3	16	3	9
11	19	11	53	11	35

In this series of experiments Sarin is about three times as effective as Tabun, which in turn is about half as effective as Gelan II.

(d) Phosgene, Tabun and Sarin in 15 cm shell

Phosgene		Tabun		Sarin	
Shells fired.	Animals killed.	Shells fired.	Animals killed.	Shells fired.	Animals killed.
10	4	3	1	3	5
10	2	5	2	3	5
10	1	5	6	3	8
30	7	13	9	9	18

The same superiority of Sarin over phosgene and tabun is again noted.

(e) HN3, CNCl and Tabun in 15 cm shell

HN-3		CNCl		Tabun	
Shells fired.	Animals killed.	Shells fired.	Animals killed.	Shells fired.	Animals killed.
10	6	10	0	5	2
10	1	10	0	5	1
10	6	10	0	5	2
10	8	6	2	5	7
10	6	10	1	5	5
10	4	10	1	5	6
10	6	20	3	5	3
9	4	10	0	5	2
9	7	10	0	8	3
88	48	96	7	48	31

Hence Tabun is more efficient as a charging for 15 cm shell than is HN-3 or CNCl though HN-3 approaches close to Tabun in effectiveness. Cyanogen chloride is not an effective charging.

(f) **Taking together all the results from shoots with pure compounds from the Vauzet - Turm we get the following descending order of effectiveness.**

Agent	Shells fired	Animals killed	Efficiency grading assuming the least efficient agent has a grading of one.
Sarin	92	194	35
Tabun	168	122	12
HN3	128	56	7
Phosgene	160	51	6
HCN	100	37	6
CNC1	145	9	1

Full Scale Shoots at Bunker Mitte with 15 cm shell

The great superiority of Sarin is again emphasised by these full scale shoots e.g.

Agent	Shells fired	Animals killed	Remarks
Tabun	84	9	Both shots performed same day.
Sarin	14	11	
Sarin	32 30	16 21	Both shots performed same day.
Sarin	24 24	18 26	Both shots performed same day.

Tabun

A large number of trials - from Vauzet - Turm and at Bunker Mitte - were also carried out to determine the best method of charging. The results of these trials may be summarised as follows :-

(a) Vauzet - Turm

Pure Tabun is better than Tabun diluted with 20 per cent chlorobenzene, e.g.

Purity	Shells fired	Animals killed
100 per cent	62	42
80 per cent	204	41

(b) Bunker Mitte

The above conclusion is not true for the larger scale shoots at Bunker Mitte e.g.

Purity	Shells fired	Animals killed
100 per cent	181	15
90 per cent	153	11
80 - 82 per cent	407	64
60 - 62 per cent	648	52
50 per cent	54	9
30 per cent	66	1

Sarin

In the shoots at Bunker Mitte, it would appear that 15 cm shell charged with 60 per cent Sarin are as effective as those charged with pure Sarin e.g.

Purity	Shells fired	Animals killed
100 per cent	67	23
60 per cent	68	21

Chemical Data are available for a few trials e.g.

Chemical Agent.	Type of Weapon.	Results.		
		Concentration in mg/m ³	Time in seconds	Distance down-wind in, m.
Phosgene 100 Kg.	3 x 30 cm. Wk	14,770	60	30
HCN 17.6 Kg.	1 x 30 cm. Wk	8,000	10	30
Tabun 28 kg.	1 x 30 cm. Wk	228	60	30
H 34 Kg.	1 x 30 cm. Wk	332	60	30

As the meteorological conditions and the animal results for the above trials are not known, comment on the chemical data would be useless.

Trials with Mustard Gas

A few trials with 15 cm shell charged Mustard Gas were carried out. The full scale shoots at Bunker Mitte gave less promising results than did the trials from the Vauzet - Turm e.g.

(a) Vauzet - Turm

Charging.	Shells fired	Animals killed
Pure H	10	5
H with 20% ethylene chloride	10	5
Pure H	10	5
H with 20% ethylene chloride	10	3

(b) Bunker Mitte

Charging	Shells fired	Animals killed.
Pure H	38 (28 on target)	0
H with 20% ethylene chloride	37	0

Thermal Generators

Tabun and Sarin have been tried in thermal generators. Sarin is the better and gives about a 50 per cent recovery. Tabun gives a smaller recovery.

Trial results with these generators are as follows :-

(a) Tabun 70 candles (20.5 kg Tabun total weight) were distributed at random over a circle of 30 m. radius and functioned. The generators burn for about one minute.

Wind S.S.W. to S and velocity 1 - 2 m/sec.

Temperature - air - 9.5°C.

Temperature - ground - 8.7°C.

R.H. - 88 per cent.

Time 1030 hours.

Lethal area of 400 - 500 m² obtained with an average concentration of 100 mg/m³ over this area.

Total effective area of 9,000 m² obtained with an average concentration of 20 mg/m³ over this area.

From the above data it is calculated that an average density of 40 - 50 g Tabun/m² would be required for lethal effect and of 2.28 g/m² to produce illness.

(b) Sarin 40 generators (9 kg Sarin) functioned over a circle 30 m radius.

Wind E.S.E. to E. and velocity at 1 m height -, 0.5 m/sec.

" 2 m " - 2.0 m/sec.

Temperature - air 12.2°C.
 " - ground 14.8°C.
 R.H. 87 per cent.

Results were

Lethal area - 3,000 m² with air average concentration of 240 mg/m³ and requiring an average density of 3 g Sarin/m² to produce

Total Effective area - 8,000 m² with an average concentration of 50 mg/m³ and requiring an average density of 1.1 g/m² to produce.

(In all the trials involving Sarin and Tabun it must be remembered, as the Germans themselves pointed out, that liquid droplets of the toxic agent may have been impacted on the skin of the animals. These may have been licked off and ingested by the animals so that both ingestion and inhalation of the toxic agents may have occurred. In the later trials the bodies of the animals were protected from contamination but the fur of the face may still have been contaminated).

Other trials included those to determine the vapour concentration from varying ground contaminations with H;

Contamination	Met. Conditions	Vapour concentrations.
100 g/m ² by hand spray.	Wind 2 - 4 m/s. Air Temp ¹ 19°C. R.H. 57 per cent Dates 18.6.40 11.15, 11.45 hrs.	Sampling 0 - 5, 5 - 10 and 10 - 15 minutes at 10 m. ³ downwind 5.52 - 5.74 mg/m ³ .
KC 250 III Gb -100 kg H Functioned statically 2400 sq.m. contaminated (35 m. from bomb)	Wind 2.3 m/s. Temp - air 21.90 " - ground 26.90 R.H. 41 per cent.	76 - 100 mg/m ³ for 10 - 15 mins. 40 - 76 mg/m ³ for 50 mins. 20 mg/m ³ for 50 mins. Trace at 90 - 100 mins. Inhalation difficulty effects down to 70 m. Effects down to 90 m. Effects over an area of 10,000 m ² (90 m from bomb)

Contamination.	Met. Conditions.	Vapour concentrations.	
30 gH/m ² By hand spray.	Wind 0.5 - 0.8 m/s.	<u>Time</u>	<u>mg/m³</u>
	Temp. <u>Air</u> <u>Ground</u>		
	0-1 hr. 26-27°	0 - 30 secs.	12
	4 ¹ / ₂ -5 " 12-13° 10°	0 - ¹ / ₂ hour	6.3
	5 ¹ / ₂ -6 " 11- 8°	4 ¹ / ₂ - 5 hours	1.4
	21-23" 19-23° 9°	5 ¹ / ₂ - 6 "	0.4
	3.5.44. 1230 hrs.	21 - 23 "	0.4
30 gH/m ² By hand spray.	Wind 0.5 - 0.8 m/s.	<u>Time</u>	<u>mg/m³</u>
	Temp. <u>Air</u> <u>Ground</u>		
	16 hr. 19-20° 8°	16 hours	0.6
	18 " 22-23° 9°	17 "	0.4
	3.5.44. 1800 hrs.		

11. Human Tests with C.W. Agents in concentration camps

On May 8th Dr. Fritz Leo, an internee, was interviewed in Belsen Concentration Camp. The following information was obtained.

In 1943, experiments with gas were carried out at the Natzweiler Concentration Camp. Professor Wimmer, of the Military Technical Institute of the University of Strassburg and of the Luftwaffe, was in charge of the experiments. The Pathology and the Anatomy Departments of the University co-operated.

Professor Wimmer contaminated the forearms of twelve habitual criminals with a liquid which Dr. Leo was later told was Mustard Gas. The men were then put to bed. The next day, there were deep areas of necrosis on the forearms, and also burns on the side of the body where the contaminated arms had come into contact. The men also suffered a severe conjunctivitis and about three days later bronchitis, which developed into bronchopneumonia.

The skin lesions were treated with wet dressings, dressings of Rivanol, and with various ointments (Boric acid, zinc oxide etc.). The Rivanol dressings were the most effective.

In spite of good treatment, three of the men died. Professor Wimmer did the autopsies and found in all cases a purulent broncho-pneumonia.

The skin lesions were photographed daily. A regular and routine urine examination was done, but no blood examinations.

Dr. Leo observed all the above except the actual contamination of the skin.

Another gas experiment was done at the end of 1943. This time a Professor Picker of the Wehr Technical Institute of the University of Strasburg was in charge. In this case 10 habitual criminals were chosen and their chests were X-rayed before the experiment. Before the test too, half the men received tablets to swallow and the other half received injections. Dr. Leo helped to grind up the tablets for the men and he was told that they were composed of Urotropin. The men were then placed in a gas chamber, two (one from each group) at a time, and were given a two to three minute exposure to Phosgene. Each succeeding pair of men were exposed to a higher dosage of Phosgene, and the prophylactic dose of Urotropin was correspondingly increased.

Dr. Leo heard that the dosage of Phosgene had been increased from 500 to 2,000. The units of dosage he does not know. Nor does he know the amount of Urotropin given.

The men all appeared normal immediately after the exposure, but all developed pulmonary oedema afterwards. This oedema was at its maximum about the third to fourth day after the exposure. All the men were confined to bed, and complained of headache and difficulty in breathing. They were cyanotic, had a lowered blood-pressure, an increased temperature, a raised pulse rate, and an increased respiratory rate. On clinical and X-ray examination of the chest the typical picture of pulmonary oedema was found. Some degree of albuminuria was regularly seen, and developed about the fourth to the sixth day.

Dr. Leo helped in the clinical treatment of the men and he also took regular X-ray pictures of the chest. The fourth and last X-ray was taken on the fourteenth day after the exposure by which time the chests were normal again. All the men were back at full work, four to six weeks after the experiment.

Professor Picker was very pleased with the result of the experiment, and some time later several SS-Officers visited the Camp to see the recovered patients. Hitler's personal doctor, Professor Brandt was one of the visiting party.

Dr. Leo had been told by SS-Officers that at other camps mass executions by means of HCN took place, but he had no personal knowledge of this.

None of the scientists interrogated at Raubkammer confessed

None of the scientists interrogated at Raubkammer confessed to any personal knowledge of these human tests carried out at concentration camps. They heard that such had probably occurred from their interrogation of Allied prisoners of war. They understood that most of the HCN manufactured was sent to PW camps for delousing purposes. At least so the Starvonal Chemical Company of Hamburg told them.

Comment:

The exact data of the above experiments would be most valuable. We believe that Professors Wimmer and Picker should be interviewed and this information obtained.

12. Summary and Appreciation

It would seem that the Germans exhibited a curiously unrealistic approach to many of the offensive problems of C.W. Thus :-

(1) As far as can be ascertained no real attempt to obtain the casualty producing dosage for H vapour on human skin was made. The Italian figures for this seem to have been taken as being of the right order of magnitude, despite the fact that the Italian C.W. organisation does not seem to have been held in very high respect.

(2) Again the offensive value of H-aircraft spray was never assessed by exposing men directly to its effects in the field. The method that they did use we have found to be open to grave errors and the existence of an optimum drop size for H spray was not appreciated.

(3) The necessity of obtaining "crash" or "surprise" concentrations with Phosgene and HCN was never stressed.

(4) No attempt was made to assess the persistence of "traversing", "occupying", or "contact" hazards, and the tactical value of such data does not seem to have been appreciated.

(5) The assessment of the harassing agents was done by means subjective methods and so their value was greatly over rated.

On the pathological side their observations closely parallel our own, though the rather late recognition of the occurrence of leucopenia in H systemic poisoning is rather surprising.

With regard to the toxicities of the common C.W. agents, their offensive dosages seem to be lower than ours, although no real effort at the extrapolation of toxicity from animal to man seems to have been made.

No new methods of treatment or specific therapies have been formulated.

Where they did lead was in the development of the new compounds, Tabun, Sarin and Soman, which would seem to have great potentialities.

13. Description of the Sections of Raubkammer that pertained to Medical Aspects of C.W.

The following Bereiche in Raubkammer dealt with Medical aspects:-
RV, RVII, RIX.

RV

This Bereich was concerned with the medical aspects of field trials. It consisted of a main laboratory and nine annexes equipped for housing laboratory animals. In addition to dogs, cats, and guinea-pigs, there was accommodation for apes and horses.



RV - Laboratory Building.



RV - Typical Animal House.

The laboratory proper consisted of some six rooms equipped to conduct all routine procedures performed in a pathological unit, including haematology and biochemistry. In addition there were facilities for preserving and mounting museum specimens.

The museum specimens were a feature of the place. The exhibits dealt largely with skin changes after application of liquid mustard to a variety of animals and respiratory system pathology following exposure to mustard vapour. In addition there were 7 specimens from cats gassed with Tabun. These presented only petechial haemorrhages in brain and congestion of stomach and intestines. There were also three exhibits of lung pathology following phosgene gassing.

No laboratory scale animal experiments were conducted in this or any of the laboratories in Raubkammer.

RVII

This Bereich, also under the supervision of Dr. Prüsener, consisted essentially of a small building containing a laboratory for clinical tests (such as urinalysis, haematology and pathological chemistry) and a library of photograph albums.

In the clinical laboratory there was equipment for animal

experimentation, but it was stated that no animal work had ever been conducted there. The laboratory had been used solely for routine blood examinations of personnel working in Raubkammer as well as special examinations of accident cases.

The photographic exhibit was the most extensive of its kind ever seen by the investigators and part of it is being shipped back for the records. It consisted of some 4,000 photographs mounted in albums and on folders. It could be divisible into two parts: the first dealing with accident cases of mustard gas poisoning and those burns occurring during field trials with the same gas; the second illustrating application of liquid mustard to the skin of men. In the first group there were over 200 different cases. The lesions were mostly skin; sometimes eye. Many colour prints were included in the collection.

Due to the gruesome appearance of some half-dozen fatal cases, the suggestion has been made that political prisoners might have been used in these experiments. There was no evidence for such a contention.

The summaries of case histories which had been prepared for the collection were said to have been burned with other documents. However these were later unearthed.

RIX

This was to be the veterinary section but no equipment had as yet been installed. It consisted of a large main laboratory building and three other buildings.



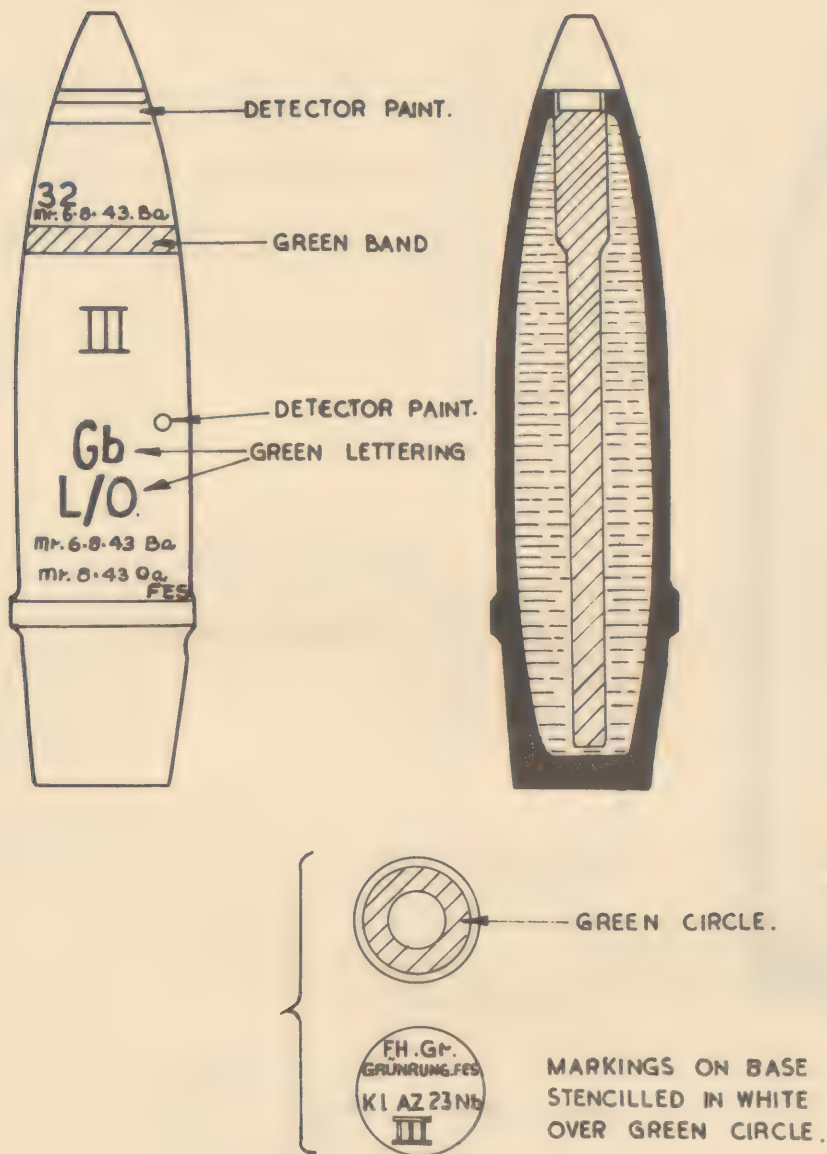
RIX - Main laboratory building (unfinished)

14. Documents recovered

The following documents have been recovered bearing on the medical aspects and are being returned :

- (1) Vergleichende Untersuchungen über den Witterungseinfluss auf die Wirkung des K.C. 250 III Gr. (9.2.45.)
- (2) Untersuchungen über die Möglichkeit eines Schutzes gegen Lstdämpfe unter besonderer Berücksichtigung der Imprägnierungsvorfahren mit Selloxin (13.2.45.)
- (3) Bericht über vergleichende toxikologische Versuche mit "D" u. "O". (18.1.44.)
- (4) Zur toxicologische Auswertung von Fliegersprühversuchen.
- (5) Vorschlag zur wohldefinierten Austestung Losten auf der Haut (8.2.45)
- (6) Mitteilungen über Gaskriegsvorbereitungen in Ausland Nr. 3.
- (7) Zusammenfassung der Ergebnisse subjectiver Prüfungen von Kanton und Kantonverbindungen.
- (8) Zusammenstellung der toxikologischen Auswertungsergebnisse von 165 Luftwaffenversuchen in der Zeit von 1935 - September 1944.
- (9) File of results of shell field trials at Raubkammer.
- (10) The German C.W. Code Letters.
- (11) Official list of the German toxicity figures.
- (12) C.W. lecture notes for medical officers.
- (13) Case histories for 200 accidents at Raubkammer, with photographs.
- (14) French list of compounds tested for toxicity.
- (15) German list of compounds tested for toxicity (complete) and indices. Recovered from Dr. Kruse.

10.5 cm. F H. Gr GRÜNRING.



WEIGHT — 13.7 Kg.

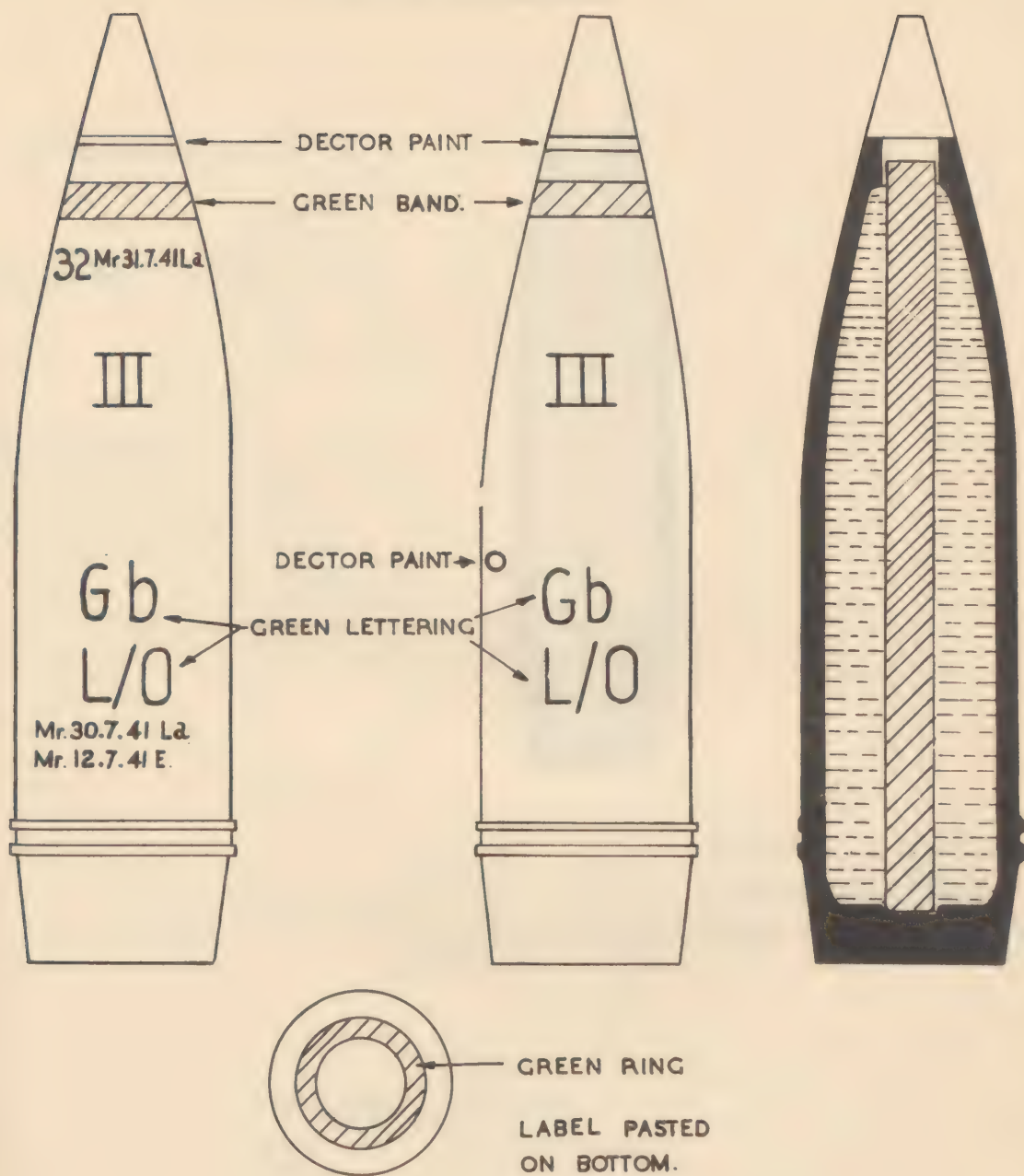
FUZE — K1 AZ 23 Nb.

CW. FILLING — 1250 cc WINTERLOST
(ACCORDING TO CODE
SHOULD BE H. ONLY.)

H E. FILLING — 125g PETN / WAX-95 / 5.

FIG I.

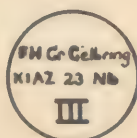
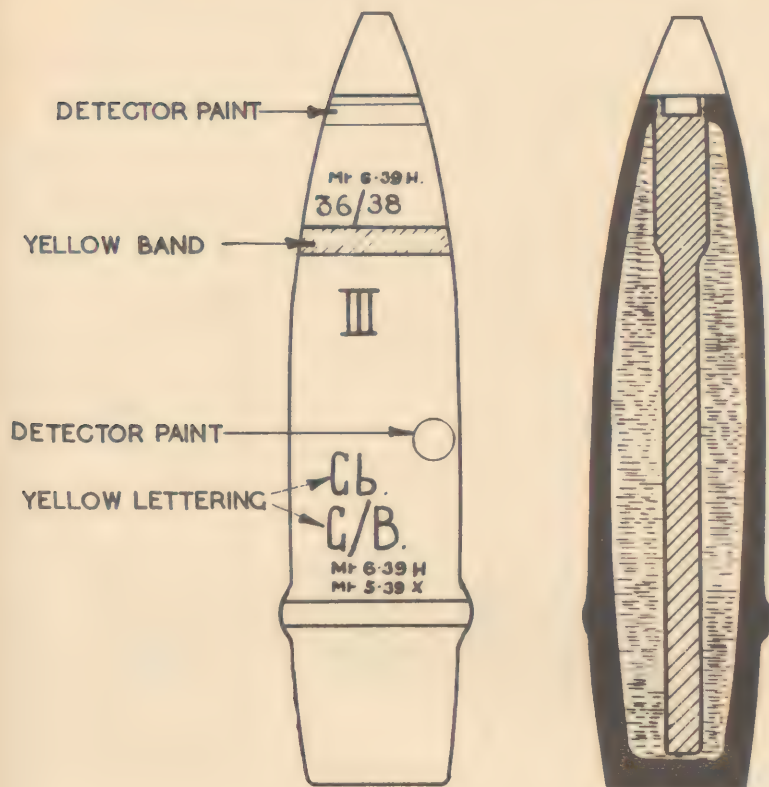
15cm. Gr. 19 GRÜNRING



WEIGHT.	• 36.8 Kg
FUZE.	• AZ 23 Nb.
C.W. FILLING.	• 3500 g.c. O (THIODIGLYCOL MUSTARD)
H.E. FILLING.	• 580 g PETN/WAX 70/30.

FIG II.

10.5 cm FH Gr GELBRING.



LETTERING ON BASE
STENCILLED IN BLACK
OVER YELLOW CIRCLE.

TOTAL WT — 14.0 Kg

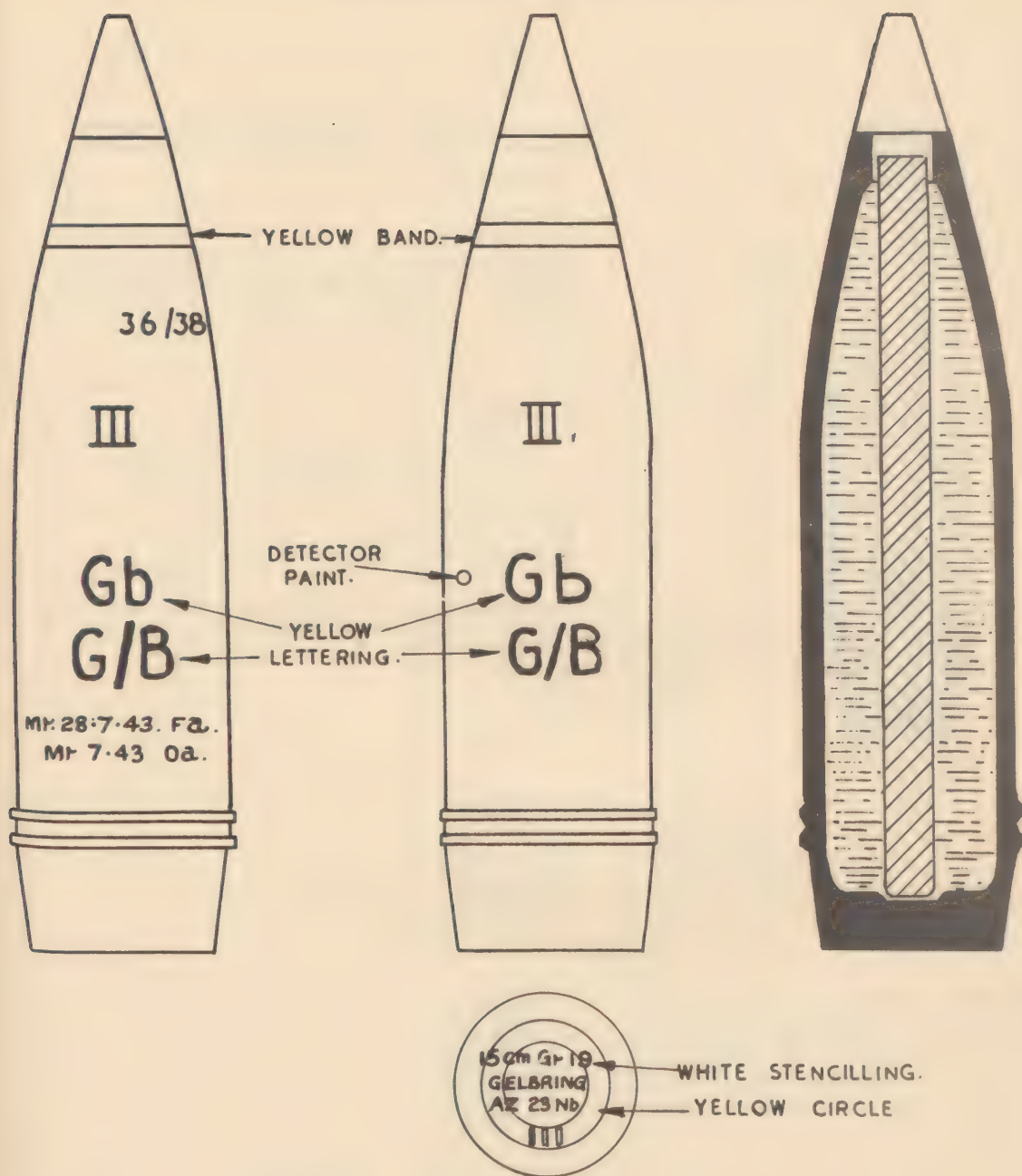
FUZE — KI AZ 23 Nb.

HE FILLING — 94g PETN/WAX-60/40

CW FILLING — 1250 cc MUSTARD-ARSINOL
(WINTERLOST.)

FIG III.

15 cm. Gr. 19 GELBRING.



WEIGHT - 37.4 Kg.

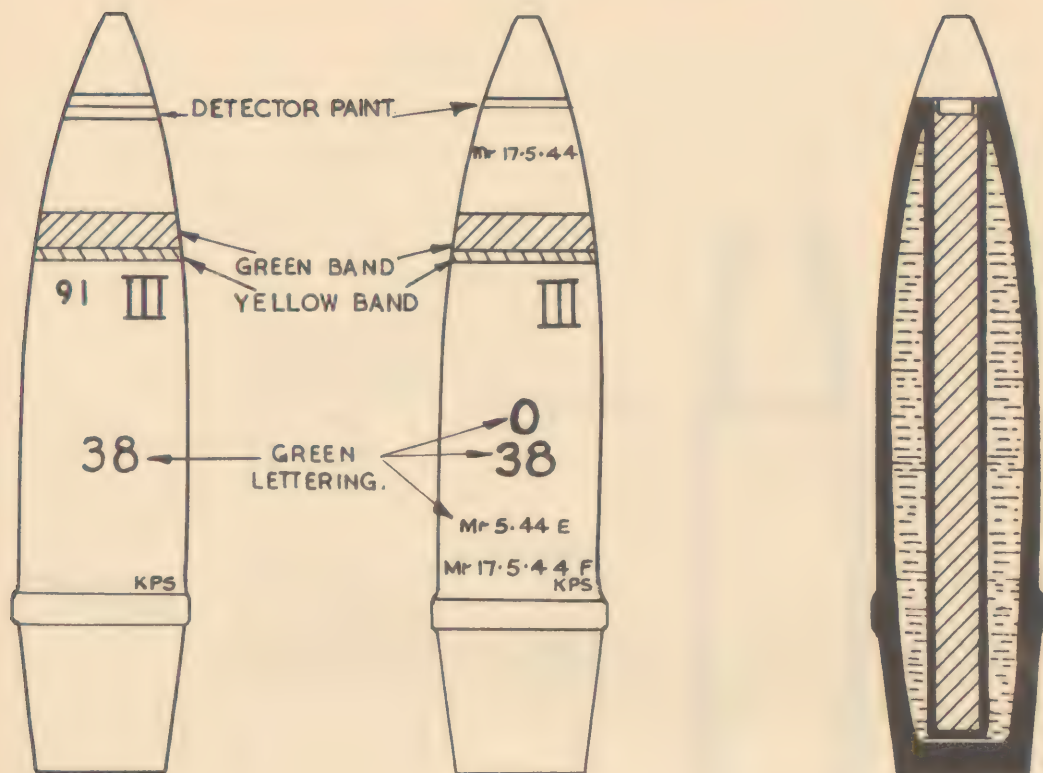
FUZE - AZ 23 Nb.

C.W. FILLING. - 3500 c.c. (4.3 Kg)
WINTERLOST.

BURSTER - 580g PETN/WAX - 60/70.

FIG. IV.

10.5 cm FH Gr 38 GRÜNRING - GELB.



LETTERING ON BASE
STENCILLED IN BLACK
OVER YELLOW AND
GREEN CIRCLES.

WEIGHT — 14.5 Kg.

FUZE — KIAZ 23 Nb.

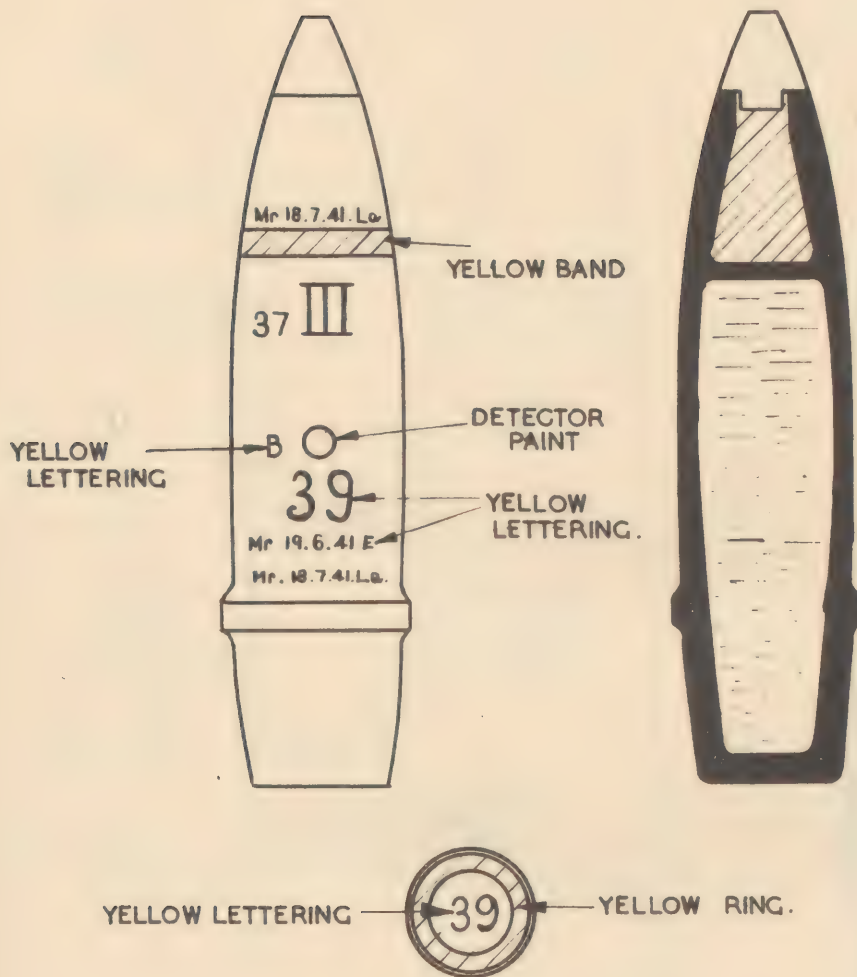
HE. FILLING — 510g of RDX 95/5
(INFORMATION GIVES 640g H-5)

CHEMICAL FILLING — 840 cc WINTERLOST.
(OA ie H + PD + DA)

ACCORDING TO CODE THIS SHOULD NOT BE
WINTERLOST, BUT STRAIGHT H.

FIG V.

10.5cm FH Gr 39 GELBRING.



WEIGHT :	= 13.3 Kg
FUZE	= KI AZ 23 Nb.
G.W. FILLING	= 1160 c.c. MUSTARD ARSINÖL. (WINTERLOST.)
H.E. FILLING	= 208 g PETN / WAX — 60/40

FIG VI.

15 cm Gr 39 GELBRING.

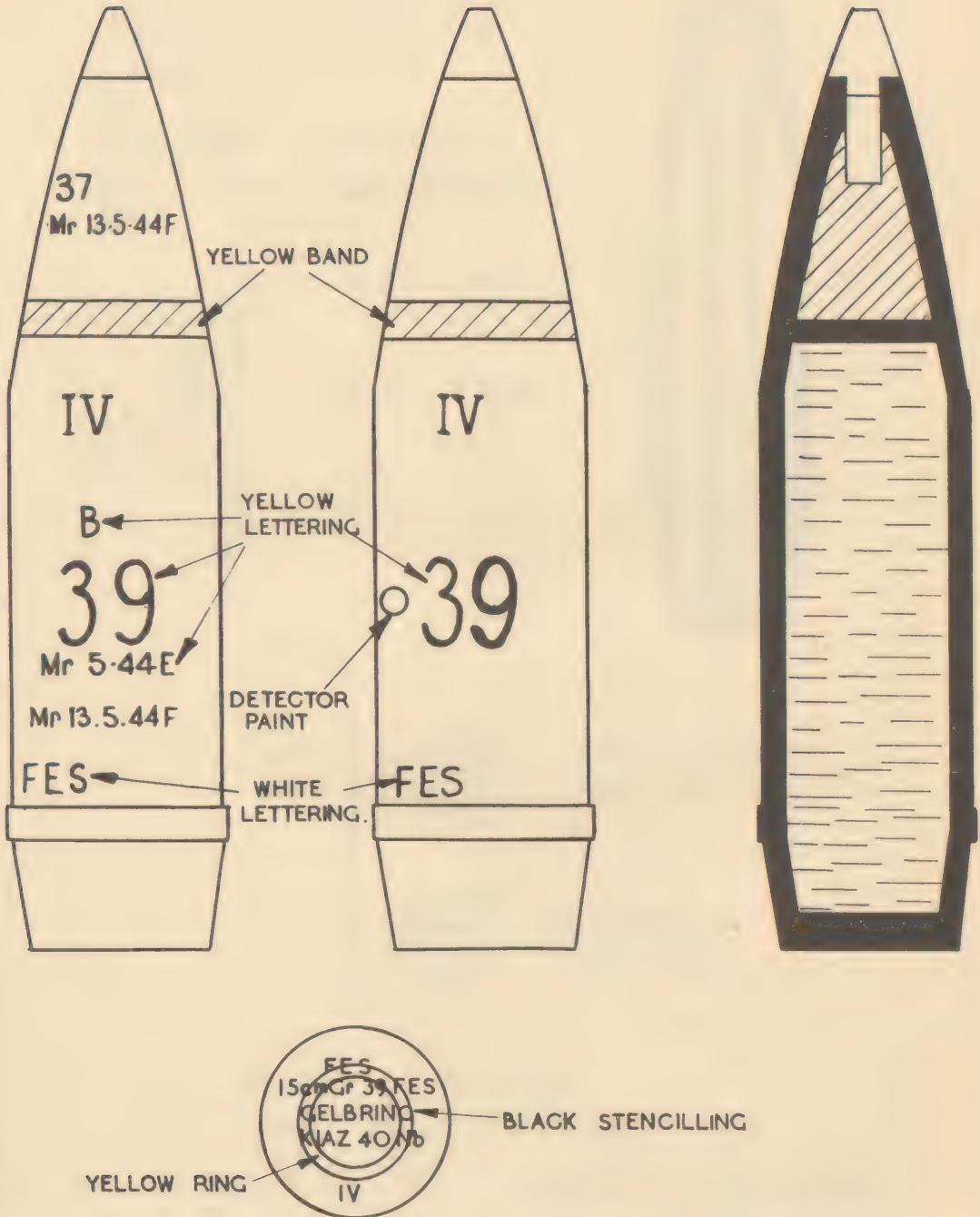
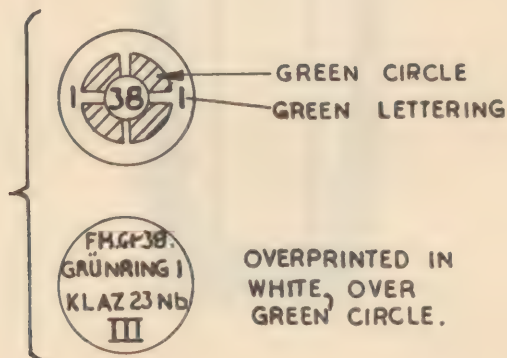
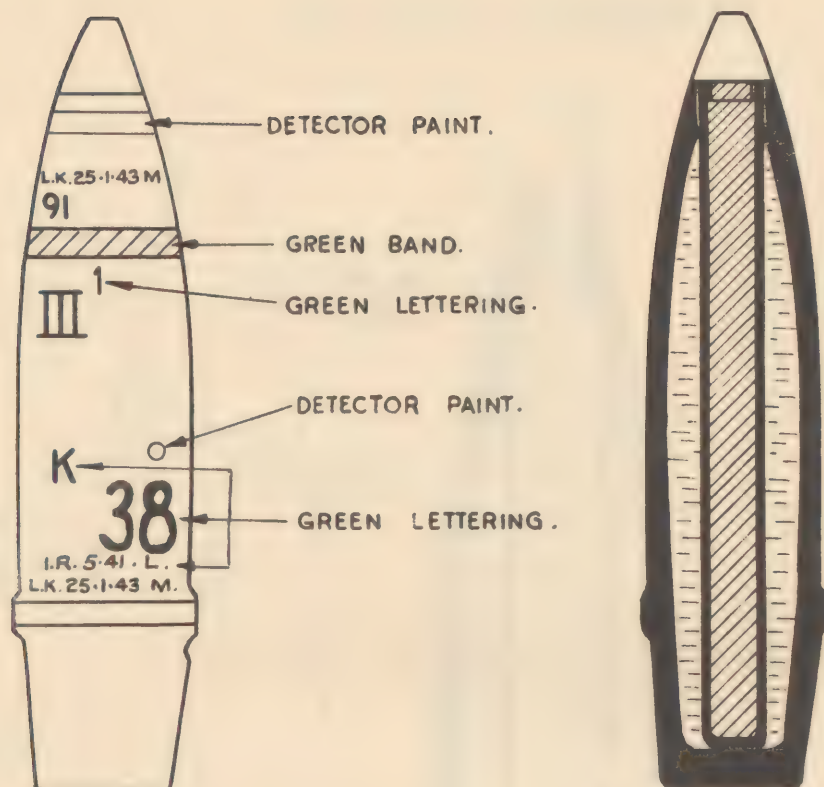


FIG VII.

10.5cm FH. Gr 38 GRÜNRING I.



WEIGHT - 14.2 Kg.

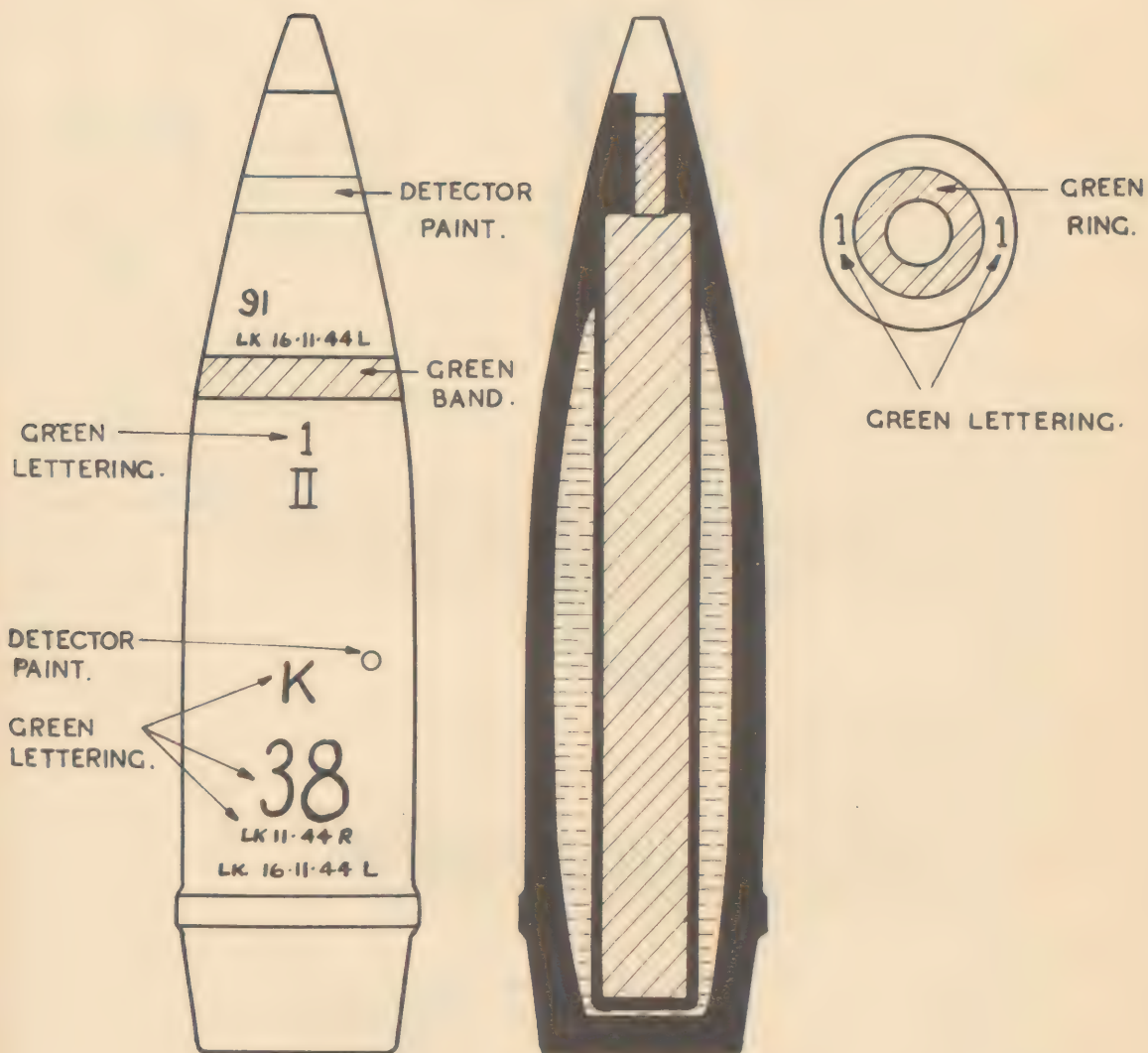
FUZE - KLAZ 23 Nb.

CW FILLING - 0.9 Kg. HN-3 (98% PURE).

HE FILLING - 0.6 Kg. RDX/WAX-95/5.
(WIDE BURSTER).

FIG VIII.

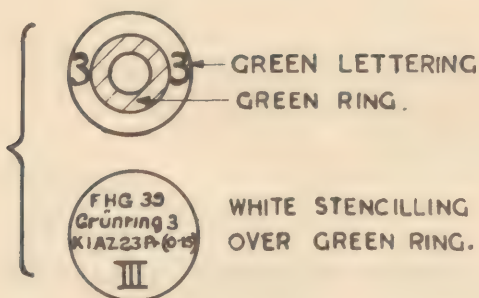
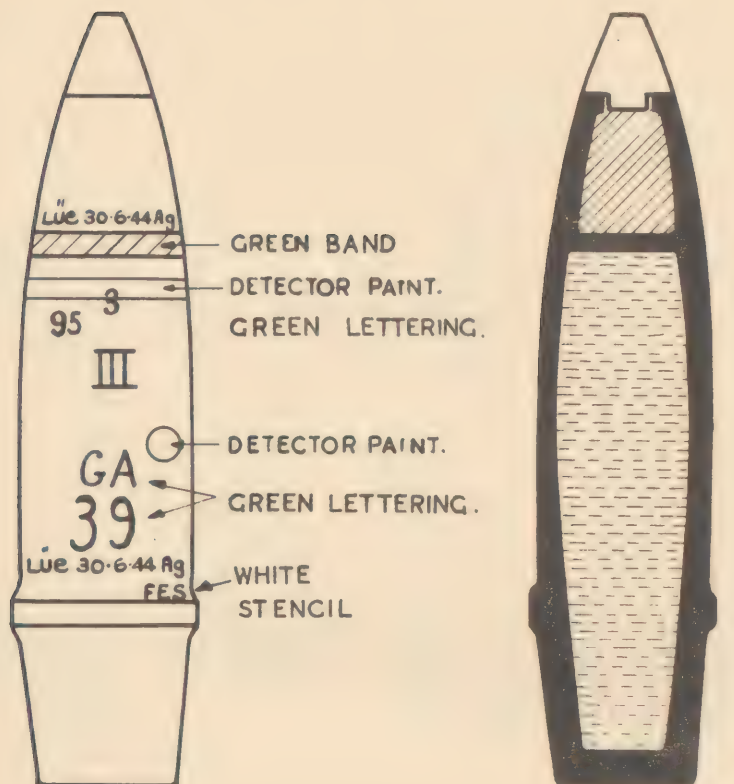
15 cm Gr 38 GRÜNRING I.



WEIGHT. -38.1 Kg
 FUZE. -K1 AZ 40 Nb.
 C.W.FILLING. -2.9 Kg HN-3 (98% PURE.)
 HE.FILLING. -2.1 Kg RDX / WAX -95/5

FIG IX.

10.5 cm FHG 39 GRÜNRING 3.



WEIGHT.

- 13.2 Kg.

FUZE

- KIAZ23 P_r(0.15)

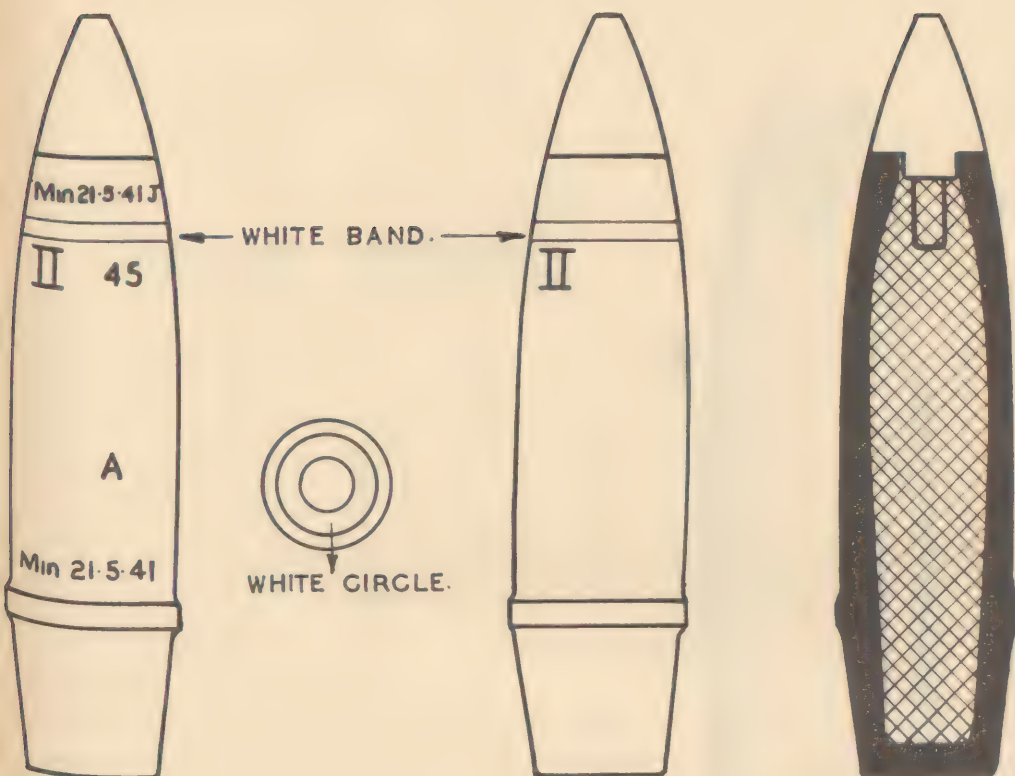
C.W. FILLING.

- 1200 c.c. G.A. (TABUN & 20 % MONOCHLORBENZENE)

FIG X. H.E. FILLING.

- 215 g RDX/TNT -50/50.

10.5 cm FH Gr WEISSRING.



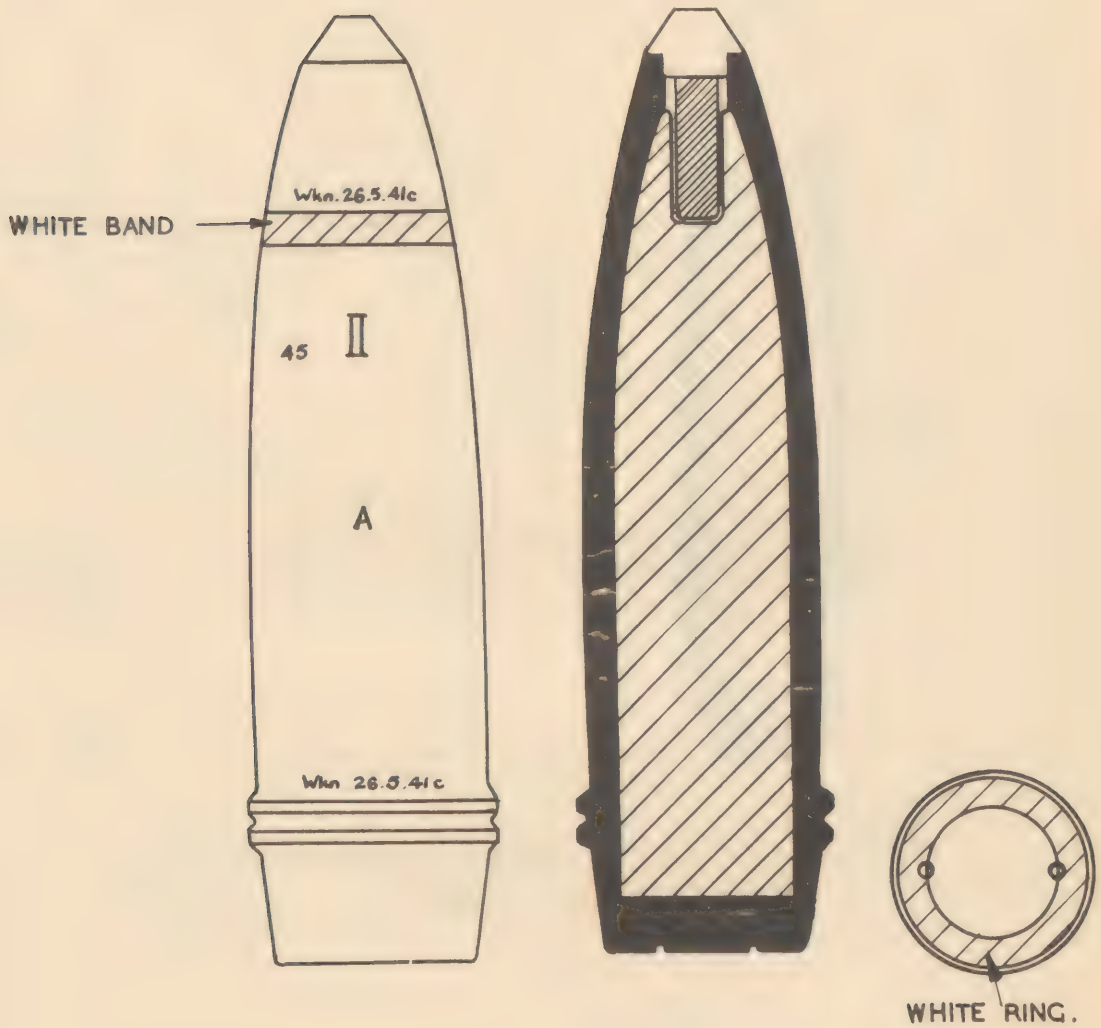
WEIGHT. - 14.5 Kg

FUZE. - AZ. 23v (0.25)

FILLING. - INTIMATE MIXTURE OF 1219g

{ CAP - 50
 PETN - 40
 WAX - 10

15cm Gr 19 WEISSRING.



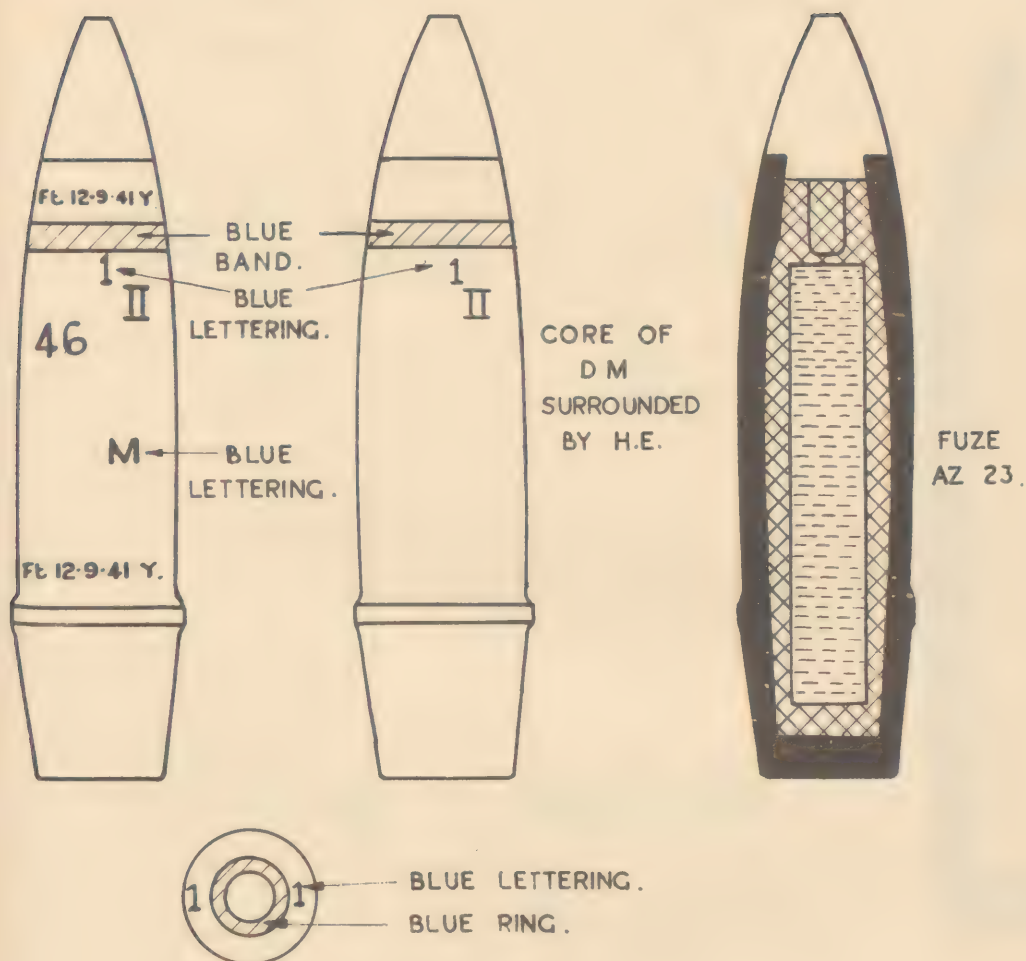
WEIGHT — 42.5 kg

FUZE — AZ 23umg (0.5)

CW FILLING— 3.5g OF { CAP — 50
PETN — 40
WAX — 10

FIG XII.

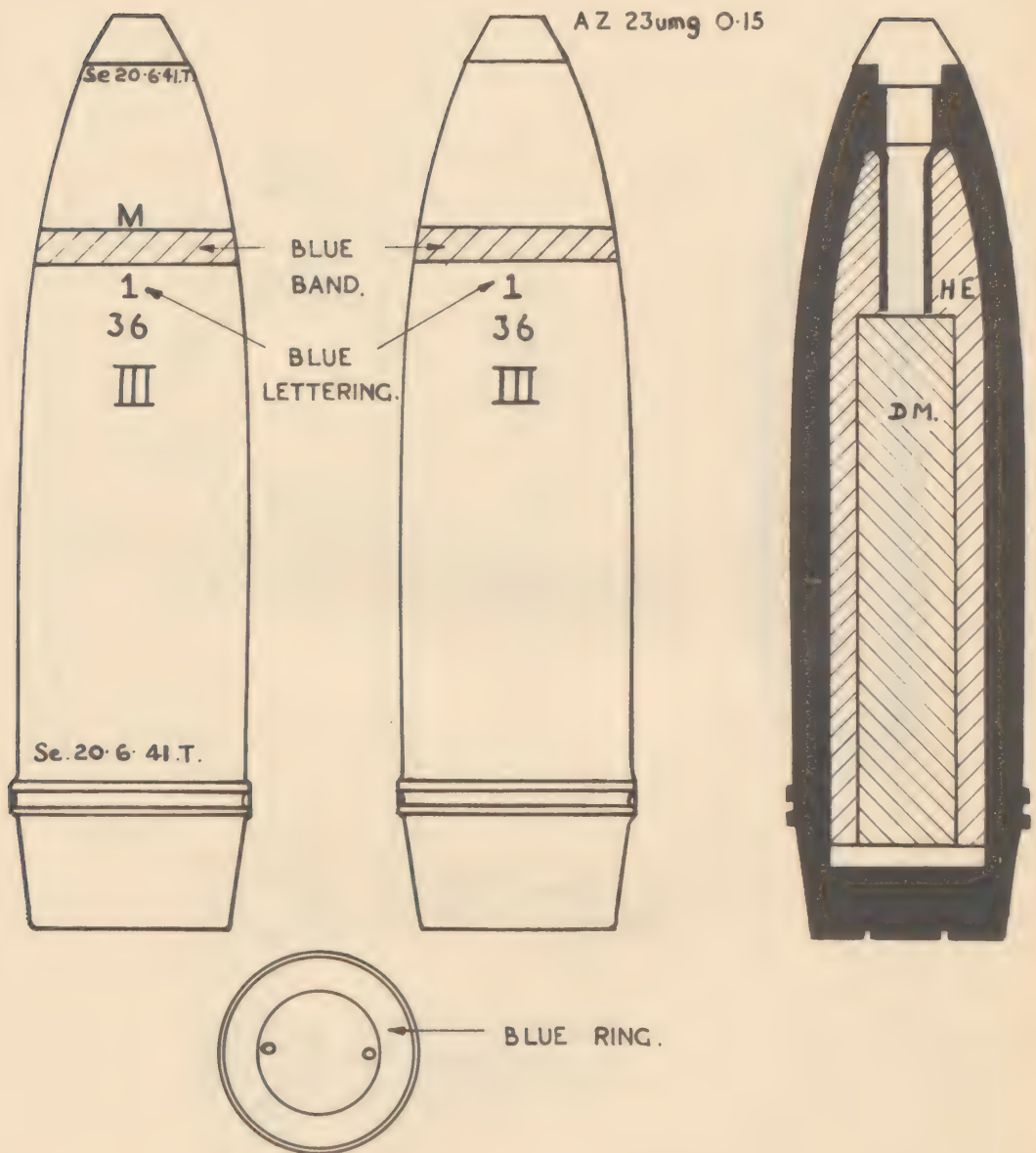
10.5 cm F H Gr BLAURING 1



WEIGHT.	- 14.8 Kg
FUZE.	- AZ 23 umg. (0.15)
C.W.FILLING.	- 550g DM (90% PURITY.)
H.E.FILLING.	- 900g TNT (LIKELY TO BE PETN)

FIG XIII.

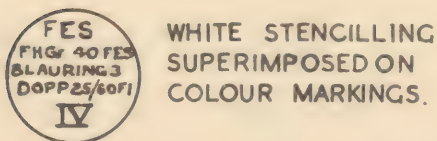
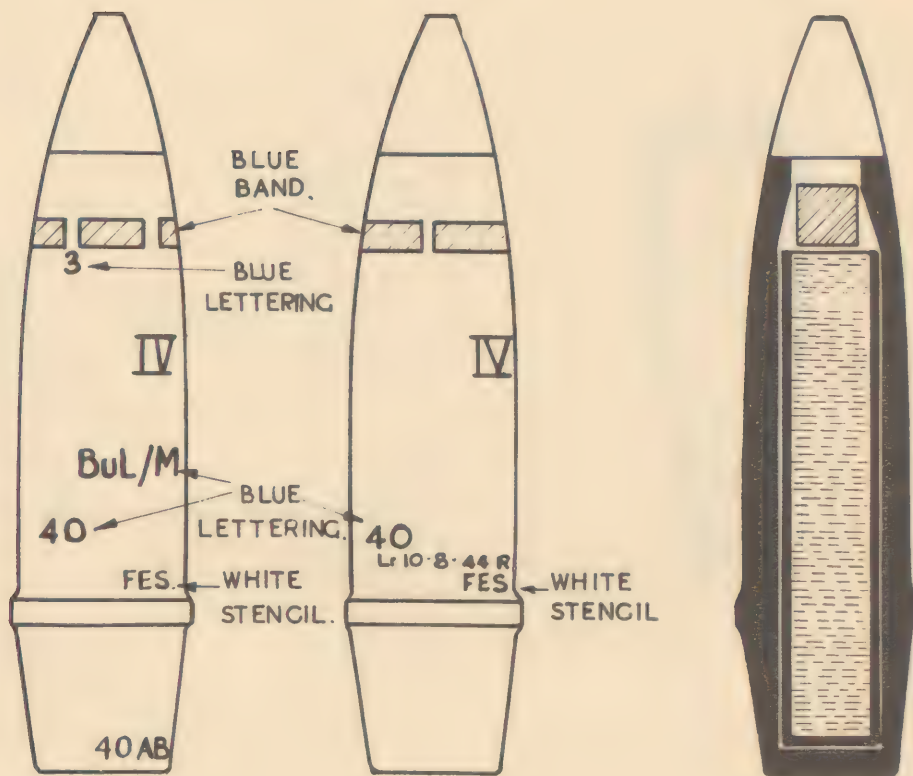
15cm Gr19 BLAURING 1.



WEIGHT.	-42.3Kg
FUZE.	-AZ 23umg (0.15)
C.W.FILLING.	-CENTRAL CORE OF 1485g DM (90% PURE)
H.E.FILLING.	-2338g PETN/WAX-75/25, SURROUNDING THE D.M.

FIG XIV.

10.5cm FHGr 40 BLAURING 3.



WEIGHT.

FUZE.

C.W.FILLING.

EJECTION CHARGE.

TIME OF EMISSION.

FIG **XV**

- 14.1 Kg

- DOPP 25/60 FL OR DOPP 25/60 V

- 837g DM/NITROCELLULOSE FLAKES 50/50.

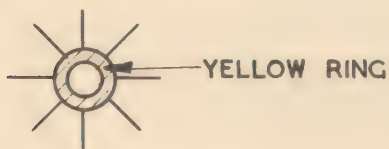
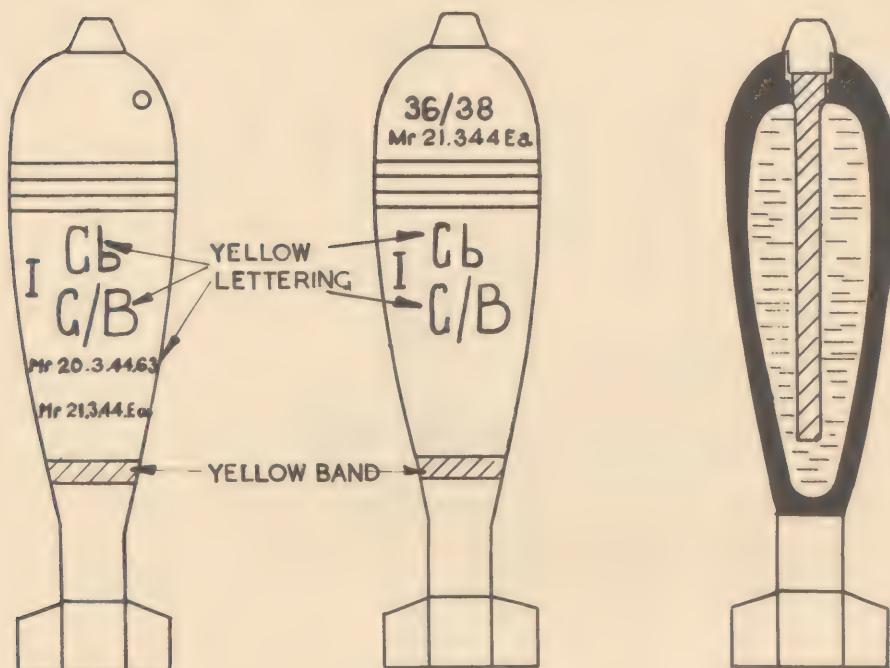
- 84g COMPRESSED GUNPOWDER.

- 1-2 MINUTES.

10cm Wgr 35 ST CELBRING.

OR

10cm Wgr 35 ST Nb GELBRING (EARLIER PRODUCTION)



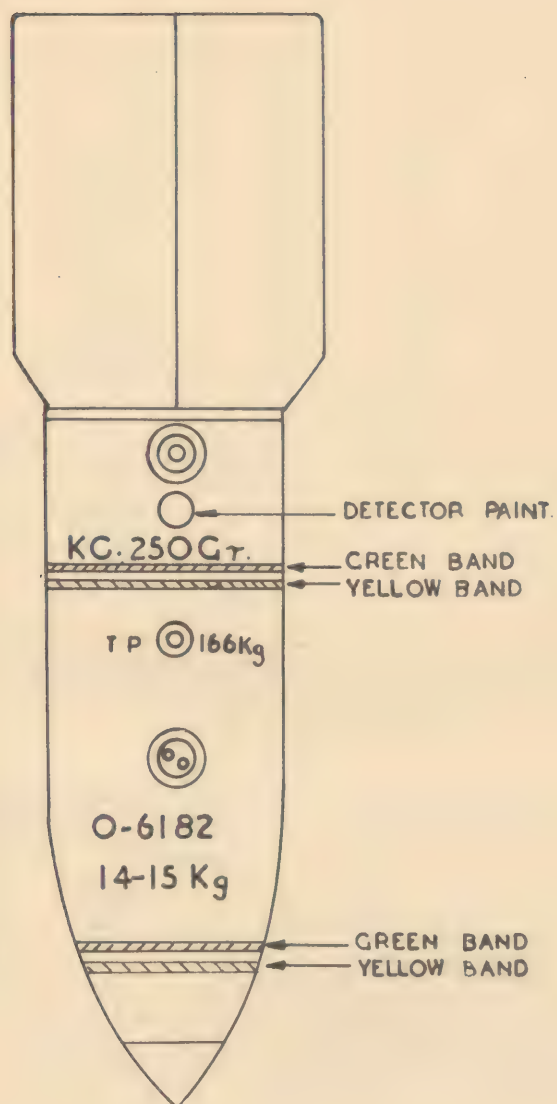
WEIGHT — 7.0 kg

FUZE — Wgr Z 38.

CW FILLING — 1080c.c. WINTERLOST.

HE FILLING — 50g PETN / WAX - 60/40

FIG XVI.



WEIGHT. - 166 Kg.

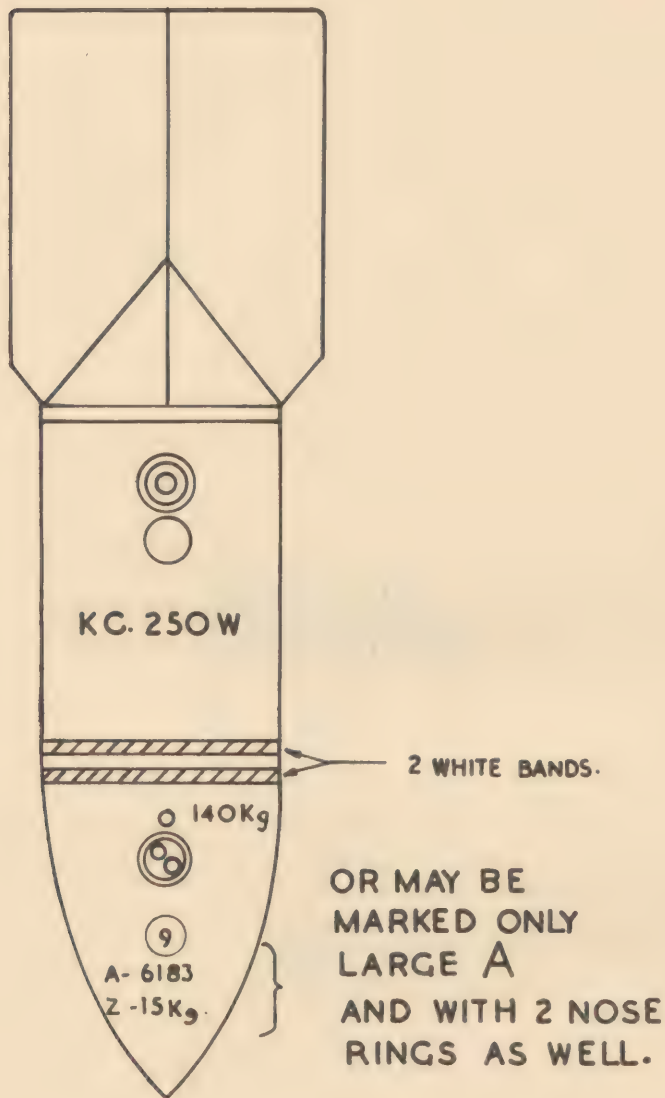
FUZE - E I A Z (26)

GW. FILLING - 100 Kg. O or B.

HE FILLING - 15.5 Kg. TNT. IN WIDE FULL-LENGTH BURSTER CONTAINER.

FIG XVII.

KC 250 W



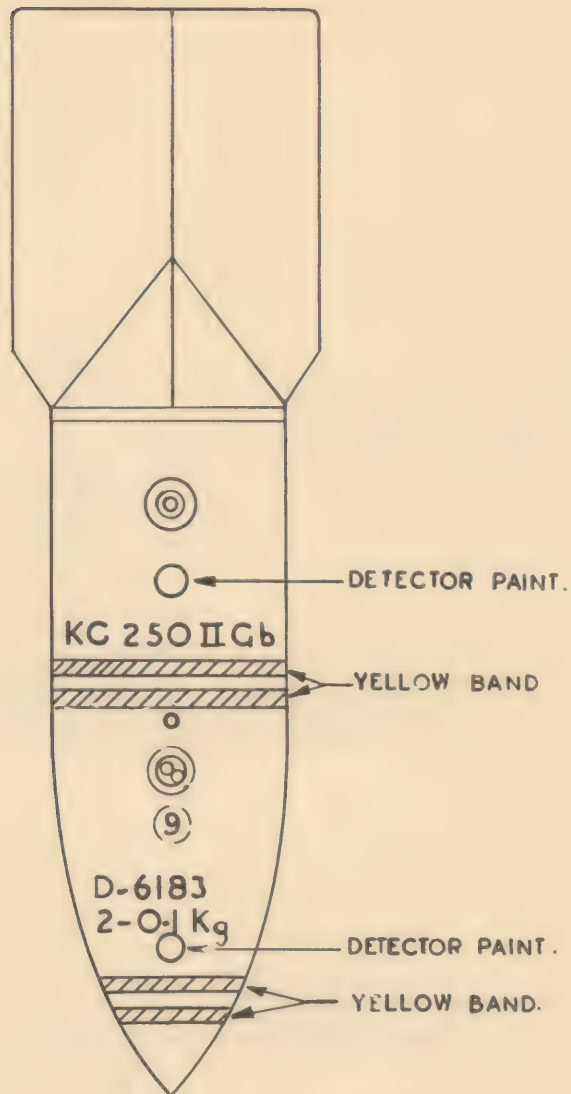
WEIGHT. = 140Kg.

FUZE. = EI AZ ⑨

C.W. FILLING. = 100 Kg. GAP

H.E. FILLING. = 0.15 Kg PICRIC IN SMALL TRANSVERSE BURSTER CONTAINER.

FIG XVII.



WEIGHT - 165 Kg

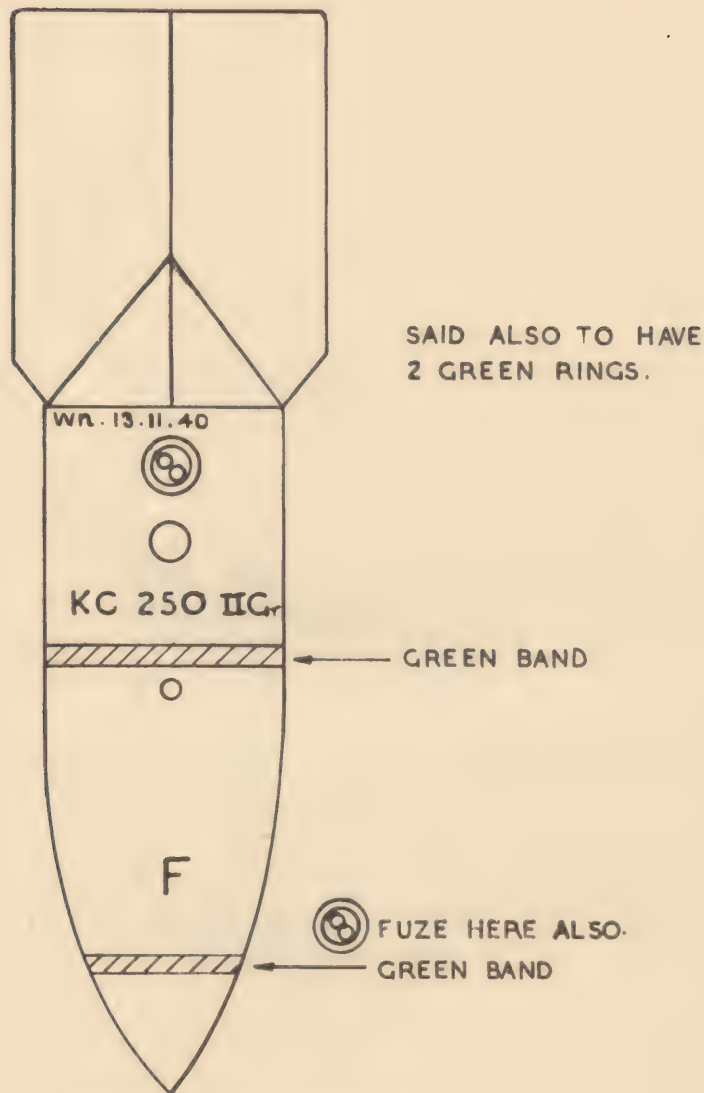
FUZE - E I A Z (9) OR (59)^a

CW FILLING - 100 Kg D or E

H E FILLING. - 0.1 Kg PICRIC IN SMALL TRANSVERSE BURSTER CONTAINER.

FIG XIX.

KC 250 II Gr.



BOMB DESIGN 6184

WEIGHT = 160 Kg.

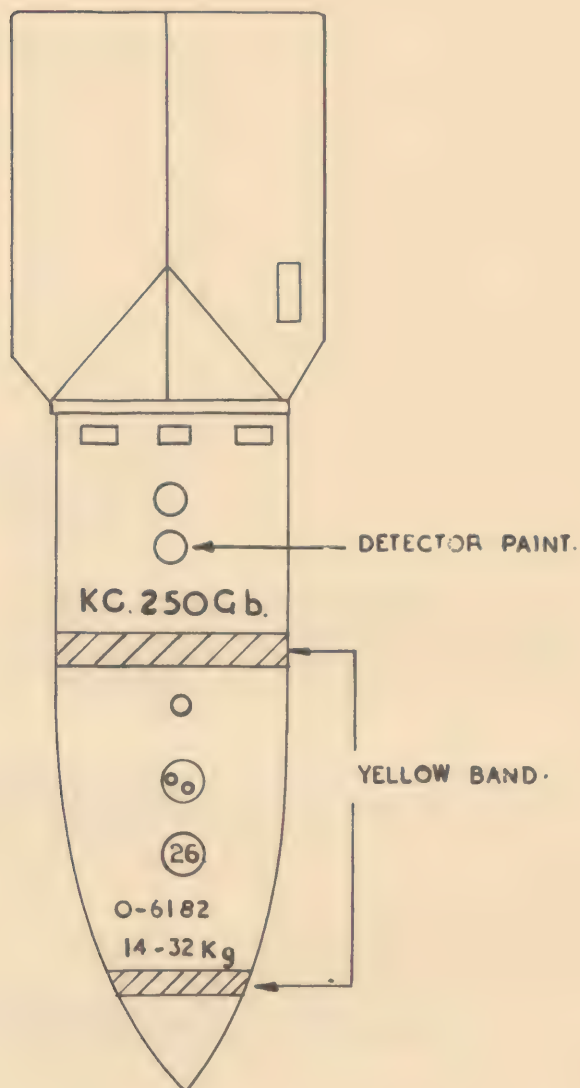
FUZE = EI AZ 55

C.W. FILLING = 100 Kg PHOSGENE

H.E. FILLING = 0.9 Kg TNT. PACKED CENTRALLY IN
NARROW FULL-LENGTH BURSTER CONTAINER.

FIG XX.

K C 250 Gb.



WEIGHT - 160Kg.

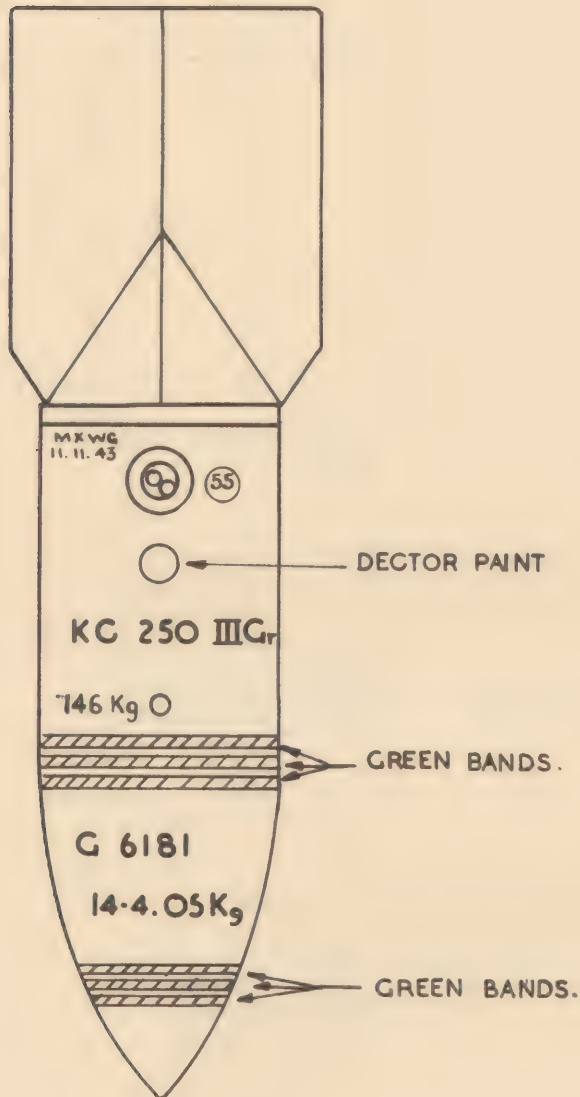
FUZE - EI AZ (26)

CW. FILLING - 100Kg O or B.

H.E. FILLING - 3.2Kg TNT. PACKED CENTRALLY IN WIDE
FULL-LENGTH BURSTER CONTAINER.

FIG XXI.

KC 250 III Gr.



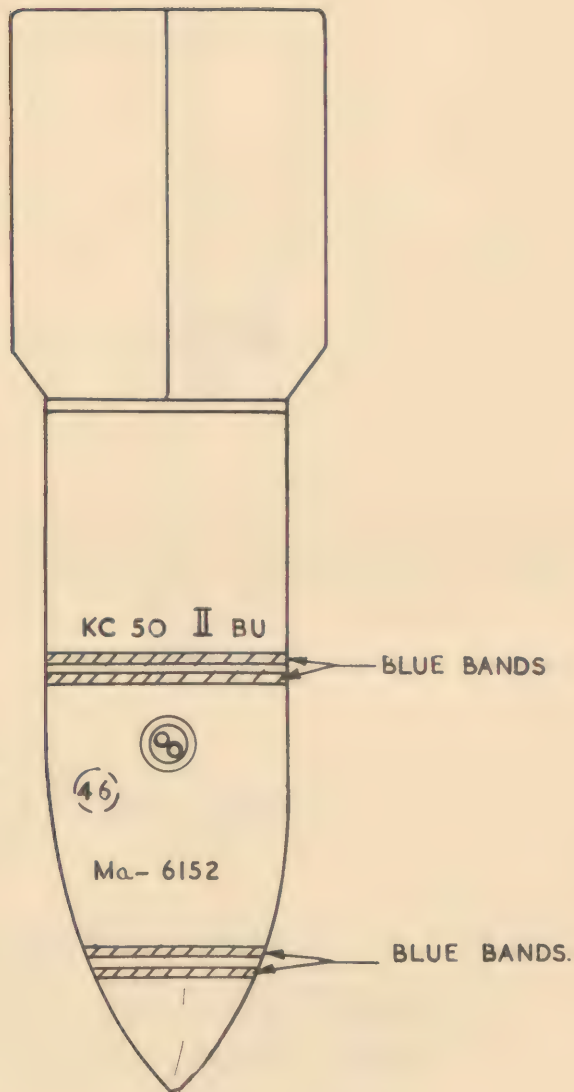
WEIGHT = 149Kg

FUZE = EIAZ (55) OR (59)a.

C.W. FILLING. = 86Kg TABUN (EITHER G or Ga)

H.E. FILLING. = 4,05Kg TNT. IN NARROW FULL-LENGTH BURSTER CONTAINER.

FIG XXII.



WEIGHT = 43 Kg.

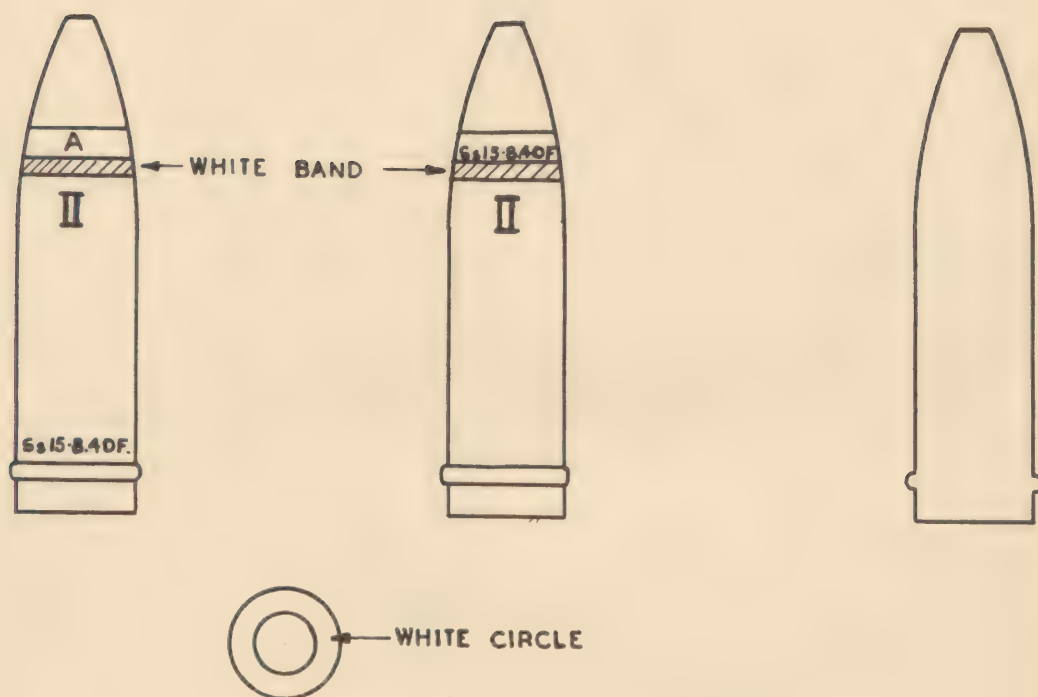
FUZE = EIAZ (46)

CW FILLING = 13 Kg (?) DM/NITROCELLULOSE - 50/50

TIME OF EMISSION 4-6 MINUTES.

FIG XXIII

7.5 cm Jgr 18 WEISSRING



WEIGHT — 52 kg.

FUZE — L Jgr Z 23n A.

FILLING — PETN — 38 %.

WAX — 12 %.

CAP — 50 %.

FIG XXIV.

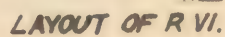
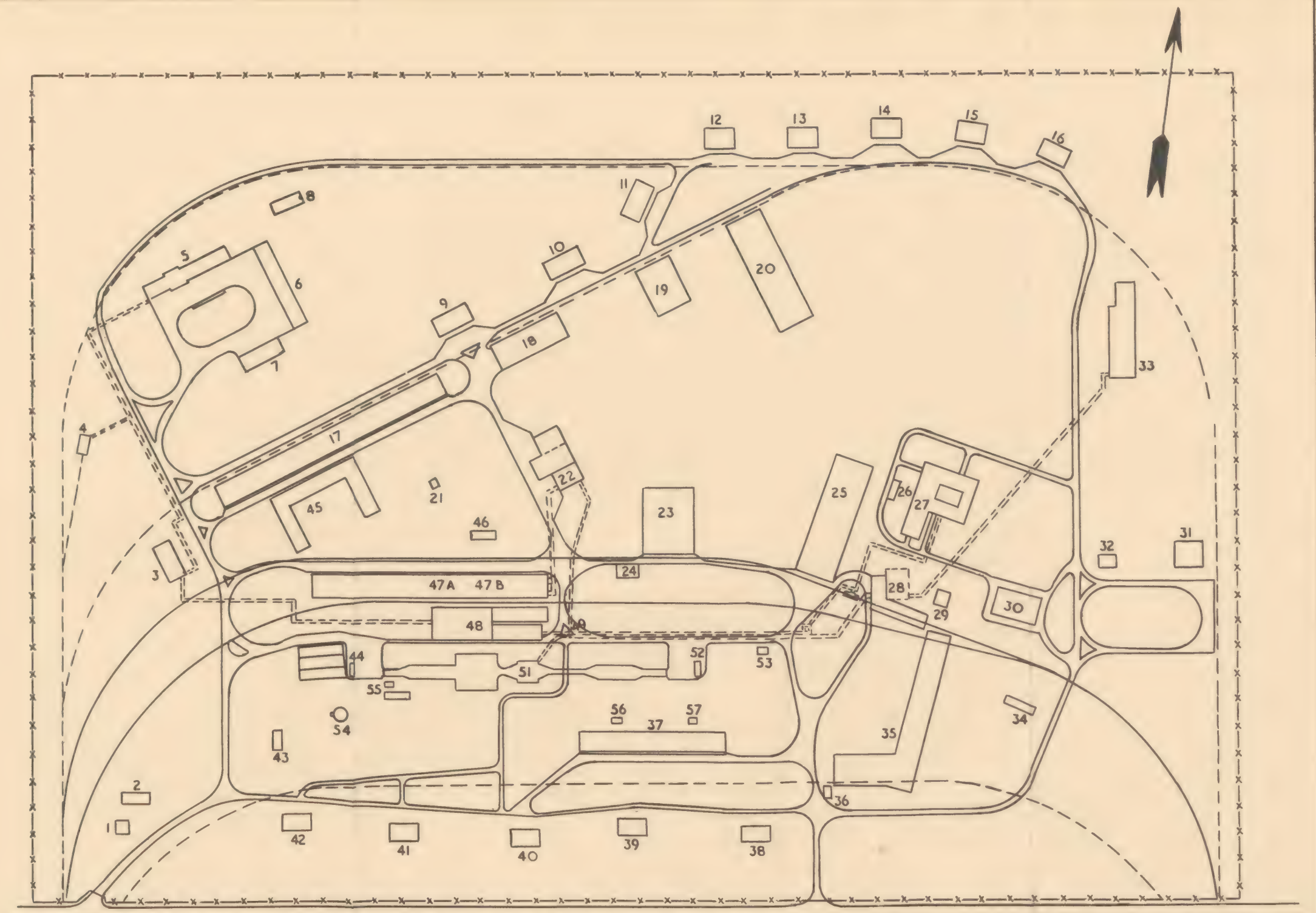
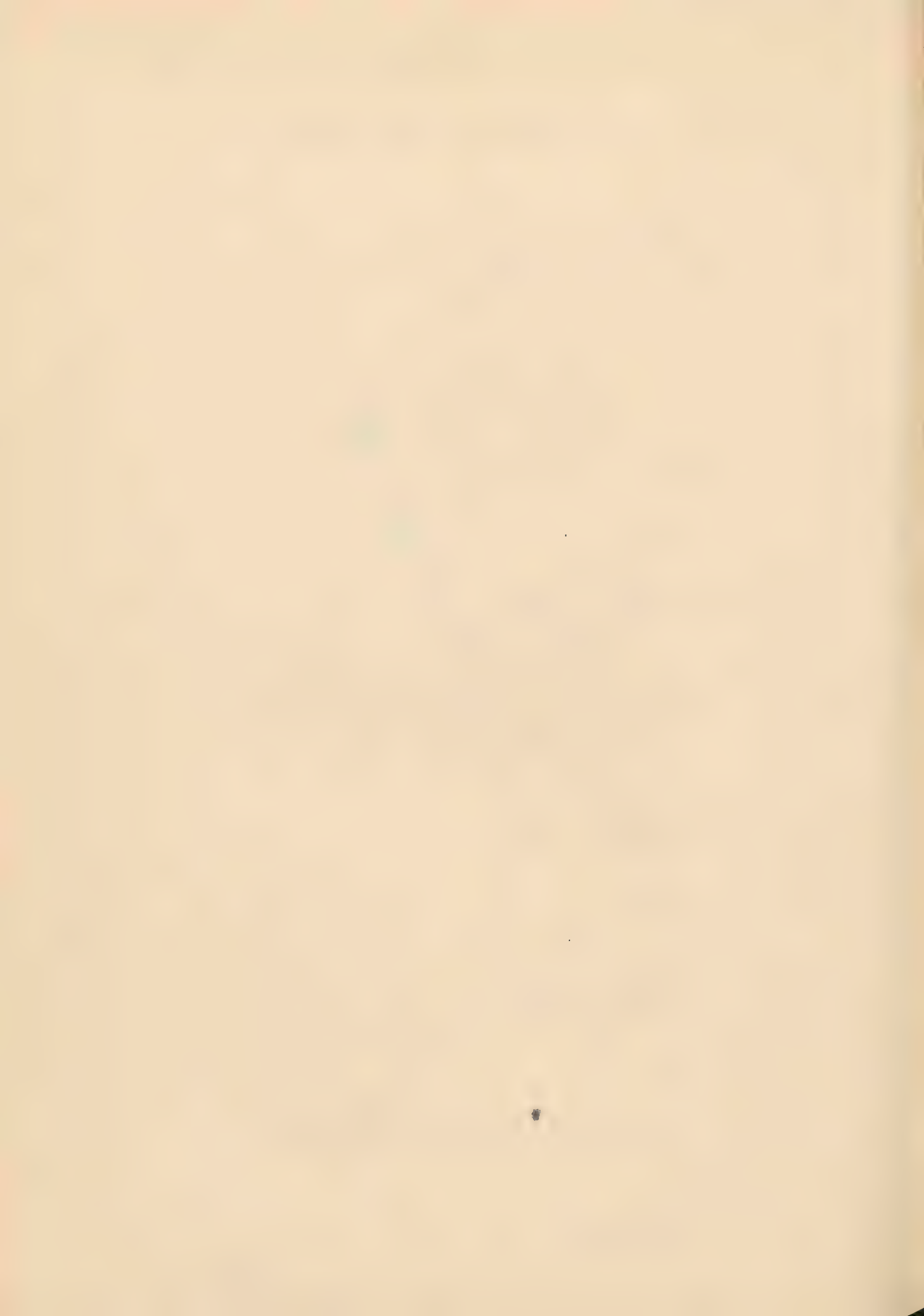


FIG XXV.



PLAN OF NEBELFÜLLSTELLE. (GAS FILLING PLANT.)

SCALE: 0 10 20 30 40 50 100 150 200 METRES.



Investigation of Chemical Warfare Installations
in the Munsterlager area, including Raubkammer

APPENDIX IV - Chemical Munitions

1. Introduction.
2. Chemical shell charged liquid gases.
3. Chemical shell charged solid C.W. agents.
4. Sealing of shell.
5. Research on shell design.
6. Thermal generators.
7. Gas Grenades, Rifle and Hand.
8. Mortar bombs charged gas, for muzzle loading mortars.
9. Rockets.
10. 20 mm. and 30 mm. shell.
11. Ground contamination munitions.
12. Hollow charge weapons using C.W. agents.
13. Aircraft gas bombs.
14. Aircraft spray bombs.
15. Toxic smoke aircraft bombs.
16. Cluster projectiles.
17. Fuzes for aircraft gas bombs.
18. Spray apparatus.
19. Future research on aircraft weapons.
20. Thickening agents.
21. Impregnated Dusts.
22. Group X of Wa. Prüf 9.

23. Miscellaneous information on chemical munitions.
24. Marking of German Chemical Munitions.
25. Charging of chemical munitions.
26. Smoke Munitions.
27. Description of Sections at Raubkammer dealing with chemical munitions.

APPENDIX IV - Chemical Munitions

1. Introduction

Development of army chemical munitions in Germany was, in its early stages, carried out at Spandau in VI L under the direction of Group VI of Wa Prüf 9. Testing in the field was undertaken at Raubkammer, the material being prepared in Bereich R VI. Some of the later stages of development work, including storage tests was also done in R VI. Luftwaffe weapons were designed in the Luftwaffe technical departments, the testing and assessment being carried out at Raubkammer under the direction of Group VI of Wa Prüf 9, acting in collaboration with the Erprobungstelle der Luftwaffe. This appendix attempts to describe weapons primarily from the development point of view, including a certain amount of historical material, rather than to give a full detailed description of all the types of munition in production. Samples of most of these were found, and are being or have been shipped back to the U.K. and U.S.A. for detailed examination, and separate reports are being issued.

This appendix also includes information on the methods of charging chemical munitions, but here again detailed descriptions of the machines used are reserved for a separate report which will be issued as a result of an investigation at the works of the makers of the machines.

The appendix concludes with descriptions of Bereich R VI, Raubkammer, the Erprobungstelle der Luftwaffe and of the Nebelfüllstelle, Munster Nord.

The following were interrogated in the course of compilation of this Appendix :-

Oberst Hirsch.
Min. Rat. Weinberg.
ORBR Dr. Nobbe.
Dr. Strasse
Oberstabsarzt Dr. Prüsener
ORBR Dr. Janssen.
Min. Rat. Prof. Marks.
o. Ing. Thiel.
ORBR Dietz.
Dr. Fench.
Dr. Mehls.
Dr. Carls.
Dr. Hildebrand
Dr. Feigs.
Dr. Hähnel
Chemiker Dr. Vogel.
Lt. Bauer.

Head of Prüf 9.
Head of Group VI of Prüf 9.
Group VI, Prüf 9.
Spandau VI L.
Group VII. Prüf 9.
Group XI. Prüf 9.
Group IV. Prüf 9.
Group VI. Prüf 9.
Bereich R IV, Raubkammer.
Spandau VI L
Spandau VI L
Spandau VI L.
Spandau VI L.
Spandau VI L.
Spandau VI L.
Bereich R VI. Raubkammer.
Nebelfüllstelle

Lt. Ritter.	Nebelfüllstelle.
Herr Trautmann.	Nebelfüllstelle.
Tech. Insp. Binnebossel	Oerrel
Hpt. Reichel	Oerrel

Standard German C.W. Munitions

The following is a list, complete as far as is known, of the German C.W. munitions which were available for issue to combat formations.

Shell

7.5 cm.	Jgr 18	Weissring	charged	Chloroaceto-phenone.
10.5 cm.	F.H. Gr	Gelbring	"	Mustard-arsinol (winterlost)
10.5 cm.	F.H. Gr 39	Gelbring	"	"
10.5 cm.	F.H. Gr 39	Doppelgelbring	"	Thickened Mustard
10.5 cm.	F.H. Gr	Grünring	"	Mustard <u>or</u> winterlost
10.5 cm.	F.H. Gr 38	Grünring 1	"	Nitrogen-mustard
10.5 cm.	F.H. Gr 39	Grünring 3	"	T.2104 + Chlorbenzene.
10.5 cm.	F.H. Gr 38	Grün/Gelb.	"	Winterlost <u>or</u> Mustard.
10.5 cm.	F.H. Gr	Blauring 1	"	DM.
10.5 cm.	F.H. Gr 41	Blauring 3	"	DM (B.E. type)
10.5 cm.	F.H. Gr	Weissring	"	CN.
15 cm.	Gr 39	Gelbring	"	Vesicant
15 cm.	Gr 19	Grünring	"	Mustard
15 cm.	Gr 19	Gelbring	"	Winterlost
15 cm.	Gr 38	Grünring 1	"	Nitrogen Mustard
15 cm.	Gr 39	Grünring 3	"	Tabun and chlorobenzene
15 cm.	Gr 19	Blauring 1	"	DM.
15 cm.	Gr 19	Weissring	"	CN.

Rockets

15 cm.	Wgr 41 wKh	Grün/Gelb	"	Mustard
15 cm.	Wgr 41	Gelbring	"	Mustard
15 cm.	Wgr 41 wKh	Grünring 1	"	Nitrogen-Mustard.

Chemical Mines

10 1 Sp.	Bü 37	Single yellow ring.	"	Mustard-anthracene oil
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10 1 Sp. Bu 37	Double Yellow ring	charged	Thickened Mustard- anthracene Oil.
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Mortar Bombs

10 cm.	Wgr 35 Nb	Gelbring	"	Winterlost
10 cm.	Wgr 35 St	Gelbring	"	"

A/C Bombs

K.C. 250	w	(Double White ring)	"	CN.
K.C. 250	Gr	(Green and Yellow rings)	"	Mustard
K.C. 250	Gb	(Yellow ring)	"	Mustard <u>or</u> Winter- lost.
K.C. 250 II	Gb	(Double Yellow ring)	"	Thickened Mustard
K.C. 250 II	Gr	(Green ring)	"	Phosgene
K.C. 250 III	Gr	(Triple green ring)	"	Tabun.
K.C. 50 II	Bu	(Double Blue ring)	"	DM.

2. Chemical Shell, charged liquid gases

The original investigation into chemical shell charged mustard started with the design of shell from, and the experience of, the 1914-1918 war.

The shell used in the last war were adapted H.E. shell and little or no research was carried out before production was put in hand.

In 1925, as the result of deliberations, it was realised that, although the existing shell were the best possible at that time, they were far from satisfactory. In this year Prüf. 8 studied the whole problem of shell design with the object of producing better and more efficient weapons.

Four designs were considered, namely,

- (a) A shell having a short burster container to give ground contamination.
- (b) A shell with a more powerful burster to give initial cloud effects.

- (c) A shell, in which the ogive was completely filled with HE in order to obtain an initial cloud effect.
- (d) A shell having a bottle of CW material embedded in the HE.

A series of trials were carried out in gas chambers, from which the only point that emerged was that Type (c) above gave the best performance from the ground contamination point of view.

Further progress was not made until some years later when it was decided to charge empty smoke shell stocks with mustard. These shell had long narrow bursters and it was hoped by using different fillings in these bursters to obtain two types of shell, (a) to give ground contamination and (b) to give an initial cloud effect.

For ground contamination picric acid was to be used and for initial cloud effect PETN. Field trials were started at Raubkammer in 1935 and it was found that the narrow burster container gave some ground contamination but a great amount of charging was lost in the crater. As, however, no other shell was then available, it was introduced into the service and charged winterlost. The picric acid burster was known as "shell filling No.88".

The picric acid burster was later replaced by PETN-Wax 60/40 and still later by a burster filled in three increments, the first and third being PETN-Wax 60/40 and the second PETN-Wax 35/65. This was the 10.5 cm. F.H. Gr Grunring shell (Fig.I) and was charged 1250 ccs. of winterlost and headfilled 125 g. of the PETN mixtures. The analogous 15 cm. shell is illustrated at Fig.II.

About the same time the same shell was charged 1250 ccs. of a mixture of H and arsenicals headfilled 94 g. of 60/40 PETN. This was known as the 10.5 F.H. Gr Gelbring shell. (Fig.III). The corresponding 15 cm. shell is at Fig.IV.

The tests for initial cloud effect were carried out using a burster of PETN-Wax 90/10.

Research was continued as it was realised that the recommended shell were still far from efficient. Two types of bursters were then considered.

- Type A a wide burster for initial cloud effect.
- Type B a large head burster for ground contamination.

During 1937-38 development went on apace, the designing of the empty shell being done by Prüf I at the suggestion of Prüf 9. Ballistic troubles with 15 cm. shell with the large head burster were encountered and work was concentrated on the 10 cm. calibre.

Type A shell gave a better performance both in the chamber and in the field. Using a strong HE it was found that 20 per cent of the charging was put up in the cloud and negligible ground contamination was achieved. The explosive used was H/5 (RDX/wax 95/5). This shell gave a good splinter effect and it was extremely difficult to differentiate between its explosion and that of a straight HE.

The empty body was known as F.H. Gr. 38 Kh and the chemical shell became 10.5 FH Gr.38 Grünring gelb. (Fig. V).

During this work on the wide burster, the information was received that the ballistic troubles with the large head burster had been cleared up and work on Type B shell then proceeded. Trials showed that this type of shell gave better results from the ground contamination aspect, less crater loss occurring.

Areas plotted by the use of detector powder and guinea pigs showed a contamination of 3 m. and 5 m. diameter circles for the 10 cm. and 15 cm. rounds respectively. Shell with the large head burster were charged 1250 ccs. of winterlost (OA) and headfilled 208 g. of PETN 60/40. This was known as the 10.5 cm. FH Gr.39 Gelbring (Fig. VI). The 15 cm. shell is illustrated at Fig. VII.

Consideration has been given to a shell which on impact with the ground would eject an inner container which would burst above the ground, but this was abandoned because it became clear that the container would probably not be thrown out onto the surface.

A similar shell to eject its container in flight was then considered, but not proceeded with on account of the number of difficult factors involved such as accuracy of fuze, ejection of containers without damage, provision of delay fuze for the containers etc.

At no time during the interrogations was any reference made to experiments or trials with, or even consideration of, air ejection of thickened liquid chargings.

An improved ground contamination effect was obtained by charging thickened mustard into shell. No details are known about this shell except that a large head burster is suspected and that the shell is marked with a Double Yellow Ring.

In 1936 the study of nitrogen mustard was taken up from the point of view of ground contamination and found to be less effective than ordinary mustard.

It was then tried as an initial cloud shell and found to be superior to mustard. The supply question had a large effect on the production aspect and on account of this the development was for initial cloud effect only. A shell having a long wide burster was introduced and was stated to be 25-30 per cent effective and was known as the F.H. Gr.38 Grünring 1 shell (Figs. VIII and IX). This shell was superior to mustard gas shell in that the area affected, while being practically the same, was more lethal. The effectiveness of the nitrogen mustard was stated to be 20 per cent greater. This figure was based on trials carried out from the Vauzet Turm using 5 or 6 shell. This shell was in production in 1939.

Owing to the high standard of protection afforded by the respirator, this grünring 1 shell was not considered good enough. A charging was needed which was undetectable and quick in action. The new compound Tabun was tried out in this shell with the wide burster. It was found that decomposition was serious and poor results were obtained. Further trials with the object of reducing the destruction of the tabun by the HE showed that the best design of shell was that having a large head burster of RDX/5 and TNT. This shell became the Grünring 3 (Fig. X).

In the 1000 m³ bursting chamber it had been found with Tabun that a wide burster container was 20 per cent efficient, a narrow one, <10 per cent and the accepted large head burster 26-28 per cent. This was calculated on a 7.5 cm. shell. Field trials gave results of the same order.

The next development was to introduce another new charging, Sarin. When tested in the 1000 m³ chamber this gave the following results using a 7.5 cm. shell.

Wide burster (190 g HE)	...	45 per cent effective
Large head burster (140 g HE)	...	30 per cent effective

This shell did not reach production but would have been Grünring 4. If HCN had been charged the shell would have been Grünring 5.

3. Chemical Shell charged solid C.W. agents

When research was started in the period 1925 - 30 only two C.W. agents were available, CN and mustard, and work had to be confined to these. In 1930, there was made available a new explosive PETN and work on the HE side had proved that the PETN had to be desensitised with wax to allow its use in projectiles.

The use of CN as the desensitiser was investigated and after a series of experiments in the chamber and in the field with

statically burst shell it was decided that a 50 per cent CN/50 per cent HETN (10 per cent wax) mixture was best. The HE effect of this 50/50 mixture was carefully measured and found to be only 15 per cent less than that of undiluted HETN. This went into production, the shell being known as Weissring (Figs. XI and XII). In the meanwhile research was proceeding with the object of developing a toxic smoke shell.

Consideration of results of trials with 1914-18 design of shell, indicated that the performance of shell with embedded bottles of DM etc. in the HE was poor, and this was confirmed by trials at Kunnersdorf in 1930-32 in a 30 m³ chamber which showed the efficiency to be of the order of 2 per cent; the majority of the charging being dispersed in particles too large to be effective. The particle size was determined by ultra-microscopic and chemical analysis methods.

Two methods of tackling the problem were decided upon

- (a) Development of a thermal generator toxic smoke shell.
- (b) Improvement of the old type in which the toxic agent was embedded in the HE.

It was realised that type (a) would involve a long research and work was concentrated on type (b).

Modifications as follows were tried :-

- (i) The inclusion of DM in a tin cylinder.
- (ii) The inclusion of Clark I in the burster container with an HE surround.
- (iii) The inclusion of HE in the burster container with a Clark I surround.

All three types were tried out under field conditions, the effects being ascertained at first by subjective tests and later when the technique was sufficiently advanced, by injector sampling.

Systems (ii) and (iii) were found to be very inefficient and as a temporary measure the system (i) was accepted.

In 1938 Arsinol and Clark I became available, and the research was reopened. Intimate mixtures of HE and Clark I were tried out, but the resulting mixture had bad storage properties. HE mixtures had been found to cause corrosion during pressing.

The type of shell finally evolved was a shell with a body forged in one piece having a central cone of a DM and Clark I mixture retained in a paper carton, this being surrounded with HE.

This Blauring 1 shell (Fig. XIII and XIV) had an efficiency of approximately 10 per cent.

The next development was that of a Blue Ring type of shell with the HE retained in a burster container. Various toxic smoke mixtures were tried out and a 40/60 mixture of Clark I in Arsenol was found to be best. In 1940, Clark II was available but owing to low solubility the mixture used was 20/80 CII in Arsenol.

Then a wide burster was introduced increasing the efficiency to 20 per cent. This shell was known as Blauring 2.

The next stage on the development of Arsenical shell was the investigation of intimate mixtures to function by thermal generation. Various mixtures of DM with vapourising compositions containing potassium perchlorate, potassium nitrate, ammonium nitrate etc., were unsuccessful owing to excessive decomposition. Nitrocellulose was more promising and a process for mixing and granulating a 50/50 mixture of DM and nitrocellulose with 1 - 2 per cent urea as stabiliser was developed by 1941. At about the same time a design for a base ejection smoke shell was perfected and in 1942-43 this shell with DM/NC charging went into production as Blauring 3 shell (Fig. XV). The 15 m. shell design had not been completed.

The firm Wolff of Bomlitz had a plant for making DM/NC near Verden. This plant, which was visited as a target of opportunity and on which a separate report will be issued, had quite a small output, the total production during the whole period of operation (3 years) amounting to about 150 tons.

The container filled DM/NC was stated to be 30-40 per cent efficient and filled as determined by chemical analysis. Experimental containers filled with Clark II/NC were stated to be 50-60 per cent efficient.

The particle size was stated to be of the order of 0.1 micron but no systematic measurements appear to have been carried out. Little attention was paid to the control of particle size since enemy particulate protection was thought to be sufficiently good to eliminate any hope of securing significant penetration.

Trials had been carried out, firing approx. 40 shell on to an area 100 x 100 m. to compare Blauring 1, 2 and 3 with the following results :-

- (i) Blauring 1 Shell were effective 500 m downwind.
- (ii) " 2 " " " 700-800 m downwind.
- (iii) " 3 " " " 1000 m downwind.

Clockwork fuzes were used for the latter and the shell opened about 300 m. from the end of the trajectory.

The view was that the generator type of shell was superior to the HE/DM type on all counts and had the supply position of certain components not been acute, all shell using DM etc. would have been of the Blue Ring 3 type.

Research on Adamsite-nitrocellulose Mixtures for aerosol production.

An account of the work which had been proceeding on this subject was obtained. Work had been carried out at VI b L by a team along five lines, viz., (a) microstructure of adamsite-nitrocellulose mixtures, (b) ignition temperature and stability at high temperatures, (c) velocity of burning and efficiency of generation of smoke, (d) effect of mixture temperature on velocity of burning.

Micro-structure. The nitro-cellulose is made plastic with added alcohol and acetone and mixed with finely ground DM (50/50). A strip of the mixture was put on the stage of a microscope and dried by warming to 60°C and the changes in structure were followed over a period of several weeks. It was found that the DM aggregates,

which were embedded in a matrix of nitro-cellulose, gradually grew smaller owing to diffusion into the matrix. Measurements of the area of the particle were made from day to day. An attempt was also made to follow the diffusion from a block of DM into a similar block of nitro-cellulose pressed against it; sections were cut from the two blocks and examined microscopically. The method was unsuccessful due to crumbling of the sections.

Ignition temperature and stability at high temperatures. In preliminary experiments the mixture was inserted into a hole in a copper block which was heated and the differential temperature between the mixture and the block measured by two thermocouples one in the mixture and the other in the block. If the temperature of the mixture is raised to about 135°C . it begins to produce smoke and the temperature then rises rapidly. It is believed that the action is catalysed by the presence of traces of metals. When the temperature is maintained at about 10°C . lower, there is practically no difference in the temperatures of the two thermocouples after the block has reached a steady temperature if the mixture is stable. On the other hand, unstable mixtures show a rising then falling differential temperature-time curve.

A much more elaborate apparatus was built in which the two thermocouples, one inserted into a block of the mixture, were raised slowly through two channels in a solid metal cylinder along which a constant temperature gradient was maintained. The thermoelements were raised by a clockwork mechanism which also moved a photographic plate on which the movements of the galvanometer spot were recorded. The apparatus was only partially completed on transfer from Spandau to Raubkammer and had not been properly re-assembled.

Velocity of burning and efficiency of generation of smoke. A strip of the mixture was ignited at one end and photographed at various time intervals. A thermocouple was embedded in the strip and the temperature rise followed. Heat is conducted from the burning zone to the unburnt portion of the strip, so that the temperature rose gradually and then shot up rapidly when the burning zone actually reached the thermocouple. A kink in the flat portion of the temperature-time curve would indicate instability of the mixture. The mixture is not isotropic and burning did not spread evenly along the strip.

The efficiency of generation was determined by collecting the fumes from the burning strip in a series of glass tubes through which acetone vapour was being refluxed. The system was not very efficient in trapping all the fumes and it was hoped to improve it by introducing a thermal precipitator by means of electrically heated wires running through the tubes. The condensate was analysed

for tri and penta-valent arsenic by potentiometric titration.

Effect of mixture temperature on velocity of burning. A rather elaborate apparatus was constructed for determining the rate of burning of the mixture when it was warmed or cooled by radiation. A disc of the mixture was fixed near the bottom of a cylindrical vessel and some way above it there could be fixed either a heater coil or also a vessel containing solid CO₂ and acetone. Thermocouples were inserted into the disc and the rate of burning and temperature measured. The apparatus could be operated at reduced pressure.

The effect of low temperature, say -30°C, was to reduce significantly the rate of burning, but this could be corrected by increasing the percentage of nitro-cellulose.

4. Sealing of shell

All shell were side charged through a threaded charging hole. Owing to production difficulties and poor sealing with the charging hole plug which was "diabolo" shaped and was screwed in on to a lead washer until the neck broke off, consideration was being given to a "driven in" tapered charging hole plug.

A small scale sealing trial at Spandau had indicated that shell stored for 6 weeks at 60°C. were satisfactory. As the result, a larger scale trial was pending but shell so sealed did not reach the production stage.

Air space. The accepted air space for all liquid chargings was stated to be 6 per cent at 40°C.

5. Research on shell design

It was stated that the following ideas and problems were to receive attention in the near future.

- (a) Production of a shell body common for HE, gas and smoke. The only variation to be allowed would be in the burster. Some bodies in the 10 cm. calibre had been obtained for trial but delivery troubles prevented much progress.
- (b) Consideration of a piston type of gas shell.
- (c) Research into methods of sealing in burster containers.
- (d) The provision of new fuzes for shell to give a quicker action.

The following is an account of some research proceeding in ViciL, Spandau on the disruption of shell as observed by x-ray and ultra rapid Cinematography.

This investigation was initiated in order to throw light on the lack of effectiveness of Tabun shell. These shell have a high yield of mist, yet animal tests gave disappointing results. Evidently the Tabun had been decomposed, but there was no evidence as to the way this had been brought about. It was thought that decomposition might have occurred in three ways: (i) by high temperatures during explosion (ii) by high pressure and (iii) by inflammation by the flash from the explosive. In the first instance, they tried to measure the temperature of the outer case of the shell by thermocolours, but these were too insensitive. Pressures could be calculated, but not the change in pressure with time. Little was known about flash. It was therefore decided to study the explosion process by X-ray and ultra-rapid cinematography.

X-ray photography. For these experiments model shell about 12 cm. long filled with water were made with plastic outer casing to secure good penetration of the X-rays. The steel burster tube was retained in the case of "kammerhulse" type shell. The X-ray photography of the burst of the shell was done at the Physikalische Abteilung of Wa.F at Gatow near Kummersdorf. The details of the process were not available, but it appears that 15 pictures with an exposure of 10^{-6} sec. were obtained by a form of drum camera. The pictures were not sufficiently rapid in succession to follow the sequence of the explosion, but there was evidence of the explosive being compressed in various zones in the central burster. The outer container was completely shattered and dispersed. No details of the interpretation of these photographs, which was done by Wa.F., could be obtained.

Ultra-rapid cinematography. This was also undertaken by Wa.F. at Gatow under the direction of Dr. Sachs. A camera designed by Crantz and Schardin capable of giving 8,000 pictures per second was used. A description of this instrument had been published in the Artillerie Monatschrift. A 7.5 cm. shell water filled on a wooden stand was exploded electrically and photographed at a distance of 50 m.

In the case of central burster shell, the nose of the shell blew off first accompanied by an initial flash and then the disruption of the outer casing proceeded progressively towards the base. The cloud of smoke from explosive mingled with the shattered charging. The nose burster shell gave a somewhat different picture. The explosion proceeded as in the first case, but the liquid cloud was pushed out behind the smoke from the explosive.

Theory of Decomposition. It was concluded from these experiments that the flash and heat production in the body of the fluid were of too short duration to account for the decomposition of Tabun. Laboratory experiments had been made by Dr. Lippert (probably now in hospital at Aschaffenburg near Berlin) on the rate of decomposition of Tabun at high temperatures and compression which lent support to this conclusion. The theory was then put forward that some reaction takes place between the Tabun and the air in the shell during flight and this accounts for its lack of effectiveness. Owing to the spin of the shell the air is under high compression and this may cause reaction with the charging.

6. Thermal Generators

The Germans thought highly of the French Engin Z and had copied the design in practically all details, after full data had been collected from the staff at Le Bouchet. They had used French ammonium chlorate and resin d'uree but used their own DM. It was intended that the Engin Z should be used from line sources.

A trial in which 120 generators were functioned 15 at a time along a 200 m. front over a period of two hours was stated to have produced a cloud which would have been sufficient to have caused troops to don respirators to a depth of 80 km. This was not a controlled trial, the main object being to check functioning, and the observations were in the form of complaints from villagers. The weather conditions during the trial were good for travel of gas.

There were various experimental designs of DM generators which had undergone a few field trials.

- (a) The Sw. Bu 100 was a generator about 15 cm. in diameter and 1 m. long. Fillings of DM/NC, Clark II/NC and CN/NC had been tried out and the following results were quoted.

- | | | | | |
|-------|------------------|--------|-------------|--------------|
| (i) | Filled Clark II, | 28 kg. | burned for | 1½ - 2 mins. |
| (ii) | " DM, | 25 kg. | " " 3 - 4 " | |
| (iii) | " CN, | 21 kg. | " " 4 - 6 " | |

A mixture of Clark II and CN was tried out but was rejected. The generators to be charged Clark II had completed development but were not in production.

- (b) A Sprüh Buchse 37 adapted for projecting a container filled Clark II/NC or DM/NC over a distance of 300 m. The time of burning of these was respectively 40-60 and 90 seconds, but only a tentative trial had taken place.
- (c) A small generator suitable for projecting from a tank and holding 800 g. of mixture had been considered but trials had not been done.

Research was being conducted on the use of new arsenicals which could be used in thermal generators. Consideration was being given to the use of Excelsior (10-chloro-5:10-dihydroarsacridine) and it had been found that this had to be of a high degree of purity to withstand storage without deterioration. If melted (m.p. 130°C.) in the presence of air or moisture, Excelsior decomposes to the oxide which is physiologically inert.

Attempts had been made to adapt the thermal generator principle to a mustard gas generator but so far with little success. Research was to be intensified on this aspect, particularly as regards the vesicant gases including Lewisite.

To prepare thermal generators, the mustard gas had been absorbed by N.C. treated with alcohol and/or ether to give a porous mass or alternatively it was poured into a generator containing the NC and shaken up once or twice. Small generators gave good results, but inflaming and explosions occurred with larger sizes.

For a container holding 600 g. NC and 350-400 g. mustard gas a 50 per cent efficiency was claimed, over a burning time of $\frac{1}{2}$ - 1 minute. These small generators were still 50 per cent efficient after 18 months normal storage. Attempts were made to vaporize Tabun by this method but serious decomposition occurred and the work was abandoned.

Sarin has also been tried and found to give about a 50 per cent efficiency.

In a trial in which 70 generators (20.5 kg. Tabun total weight) were distributed at random over a circle of 30 m. radius and functioned, a lethal area of 400-500 m² and an effective area (20 mg/m³) of 9000 m² were obtained.

A similar trial with 40 Sarin generators gave a lethal area of 3000 m² and an effective area of 8000 m².

Research was proceeding on mixtures of NH₄ClO₄, sawdust and/or peat and on modifications in the design of the container. The final

view taken was that a generator in which the products of combustion passed through unburnt composition would be satisfactory provided that (a) the correct emission holes were used. (b) layers having different speeds of burning were present in the generators.

7. Gas Grenades, Rifle and Hand

The Rifle grenade 42 charged smoke $TiCl_4$ or $TiCl_4/SiCl_4$ is well known and has been previously examined. Trials were carried out with this munition charged 102 cc. of AC against Russian T.34 and T.60 and General Lee tanks. The AC frequently caught fire during these trials.

Cats were used as test animals and the conclusion was that if the grenade hit the base of the turret and provided inflaming did not occur the result would be satisfactory. The efficiency of the weapon depended to a great extent on the internal construction of the tank. If the crew were partitioned off from the driver it was thought but not proved that the effect would be reduced. It was thought that even if death did not take place, the crew would be rendered unconscious for sufficient time to enable the tank to be captured intact or destroyed.

Grenade 60 was similar to the 42 except that it held 148 ccs. of AC. It was not an accepted munition.

The hand grenade 24, usually filled smoke, was tried out filled with a mixture of CN/HE on the white ring shell. Trials in the open gave effects at 200 m. but no further work was done.

The hand grenade 41 was tried out charged 175 ccs. of 60/40 CN/chloroform solution and opened by a burster of 30 g. PETN. The performance was assessed at 12 per cent efficient. A solution of 40/60 CN/chloroform was tried but found to be inferior. The efficiency was assessed by subjecting troops to the effect of the grenades and then carrying out a marksman's test. The 41 and 24 grenades were assessed in this way. Trials with this grenade charged AC and CN were carried out against bunkers and the AC was assessed at 90 per cent efficient. Later trials with Tabun indicated an efficiency of only 8 per cent. A mixture of 28/72 Excelsior in methylene chloride was also tried out but the results are not known.

A new experimental grenade of the 41 type had been tried out filled 180 g. DM/NC giving a toxic emission lasting for 10-20 seconds. No further work was done.

Trials were also carried out both at Spandau and Raubkanmer with glass bulbs charged 130-180 ccs. of AC. Tanks were attacked, using cats as test animals, with excellent results, one bulb or at the most two being sufficient to give a lethal dosage within the tank. The results were stated to have been checked by chemical analysis.

A glass grenade known as the H.W.K. had passed its trials of experimental production and a few thousand had been made and packed. The Army authorities had agreed to its use and were not worried about the danger to the user due to breakages, the intention being to keep the bulbs in their wooden boxes until the last possible moment. A percentage of water was added (? 20 per cent) to reduce the freezing point of the AC.

Tabun and Sarin had been considered as chargings for glass bulbs but owing to the difficulty of experimenting with these gases, due to the contamination of the tanks after trial, and the fact that HCN was considered sufficiently good, no actual trials had taken place.

A few observations common to the use of AC in any weapon might be made here.

AC was not in quantity production and there was no intention of using it on a large scale for C.W. purposes. It was supplied mainly in soldered tinned plate containers of about 4 litres capacity and no difficulty in transporting or storage had been encountered.

AC was stabilised by the addition of 0.2 - 0.3 per cent of SO₂ or of oxalic acid. The former method had given satisfactory results on a 9 months storage trial at 60°C.

Inflaming had been experienced and attempts had been made to overcome it in several ways.

- (a) In small grenades, a pellet of inert material such as NH₄Cl, NaHCO₃, NaCl was placed below the explosive where the latter protruded into the AC portion of the grenade.
- (b) In larger munitions, an inert surround of the explosive was made. This method depended on the diameter of the HE charge.
- (c) The addition of water to the AC was mentioned as being effective in preventing inflaming but this was contradicted from other sources.
- (d) The addition of CK had been tried but the resulting mixture would not store; it also gave indications of gas by lachrymation.

It was understood that the problem of inflaming of AC had not yet been solved.

8. Mortar Bombs charged gas for muzzle-loading mortars

In 1935 there was in existence a 10 cm. smooth bore mortar bomb for HE charging known as the 10 cm. W Gr. 35. This was adapted as a smoke bomb by the inclusion of a burster container and charging CSAM and SO₂. This bomb had a long wide burster and was tried out with a mustard charging. It was not very efficient, only a small amount of the charging being thrown clear of the crater. Nevertheless in 1938 it went into production charged mustard (OR) as the 10 cm. Wgr 35 Str Gelbring (Fig. XVI.).

In 1938 a new mortar was produced which would withstand greater propellant pressures. The mortar was the 10 cm. 40, and work was done to design a new bomb capable of withstanding the higher pressures. However, before a design of bomb was cleared, the mortar itself was rejected and no further work was done.

There was however, the 8 cm. mortar and at the beginning of the war smoke ammunition was available for this calibre. A demand arose for a HE and a gas bomb but owing to the small capacity of the bomb only CN was considered as the charging. The original intention was to embed a pellet of CN in the HE and owing to urgency this method was used. It was admitted that the gas effects are very poor and ineffective except in the immediate vicinity of the burst.

It had been found that the Russian 12 cm. mortar was an excellent weapon and a 12 cm. bomb was being developed when the war ended. The intended chargings were smoke, mustard gas and Tabun.

The 8 cm. and 12 cm. mortars were infantry weapons and the 10 cm. was primarily for the Nebeltruppe.

The ranges of these mortars were given as follows :-

8 cm.	-	very short range.
10 cm.	-	3500 m.
10 cm. 40	-	6000 m.
12 cm.	-	8000 m.

9. Rockets

In 1934 the trials with 10 cm. Wf. gr. started, only a smoke charging being considered. The propellant was black powder and the bomb was of normal design i.e. bomb leading with a tail motor. Attention was paid to the 15 cm. size and a similar design was used, black powder still being used as the motive power. Then owing to ballistic troubles a forward motor was developed, and preliminary trials showed a much enhanced effect with HE, Smoke and Gas. This was considered to be due to the motor acting as a stick fuze.

A large production was made of this 15 cm. rocket as follows :-

- | | | | |
|-----|-------------------------|--|--------------|
| (a) | charged SO ₃ | with a narrow burster. | } Nb |
| (b) | " | SO ₃ " " wide " | |
| (c) | " | OA mustard with a wide burster. | Yellow ring. |
| (d) | " | Mustard or nitrogen mustard with a wide burster. | Green ring. |

The introduction of this 15 cm. rocket rendered the 10 cm. mortar obsolescent.

Attempts were made to design this projectile to carry a smoke generator but the heat of the propellant gases caused preignition and bursting of the bomb.

It was intended to investigate the possibility of incorporating a toxic smoke generator but so far preliminary trials had not been successful.

The weapon was not accurate and trials had shown that a very large ammunition expenditure was required to obtain satisfactory results on the target area. Trials with a shortened bomb confirmed the view that such a bomb with a wide burster would be more stable in flight. This design was cleared for production but as far as is known none were charged.

A 21 cm. rocket with a rear motor was designed by Prüf. I. The Army authorities refused to have this weapon charged gas but agreed to smoke. It had a range of 7500 m. The Prüf 9 view was

that for HE gas and smoke a forward motor was essential for good performance but Prüf.I insisted on a rear motor.

For the war against Russia they had designed two bombs, each using the standard 15 cm. motor.

- (i) a 28 cm. rocket charged HE.
- (ii) a 32 cm. " charged incendiary mixture.

A 30 cm. rocket head was designed to be carried on the 21 cm. motor and these bombs were to be charged phosgene, AC and Tabun. During development several troubles were encountered such as a large 100 per cent zone, and ignition of the AC. The usual method of surrounding the HE with an inert material to prevent ignition of AC had been tried with little result.

Trials with Tabun in the 30 cm. bomb had indicated such a good performance that production was planned but not started.

Large scale shoots with bombs charged AC, phosgene, and Tabun gave areas of 600 m. x 250 m. for fall of shot. Bombs charged phosgene were best, giving an area of 400 m. x 200 m.

Attention was to be given to the inclusion of longitudinal baffles inside the bomb to improve ballistics.

10. 20 mm. and 30 mm. shell

Trials had been carried out using

- (a) AP shot with the tracer cavity filled CW agent.
- (b) HE shell with the complete shell filled C.W. agent.

Using CN, DM, Excelsior and Soman, it was found that little result was achieved with the AP shot.

With the HE/I shell, however, better results had been obtained particularly against light protection. It is worthy of note that the time fuze was included in the round and in the case of solid CW agent was protected by a waxed or metal disc.

Mustard gas had been tried as a charging but in this case it was necessary to charge the mustard into an inner liner, which after sealing was slipped into the HE/I shell and fused in the normal manner.

Small static trials were carried out at Spandau and in the Raubkammer 18,000 cub. m. Messhaus.

An excellent performance was stated to have been given by a 3 cm. shell charged Excelsior. This shell was charged by using a liner and this in turn was filled in three increments, HE at either end and Excelsior in between.

It might be noted here that methods of charging in which Excelsior had to be melted should be avoided if possible, since in the presence of oxygen or traces of moisture decomposition to the inactive oxide takes place. A 70/30 mixture of CN/PETN was tried out with little success.

The use of AC was not considered owing to the small capacity of the shot.

A trial had been carried out with a 7.92 mm. round charged $TiCl_4$. This was abandoned but Excelsior placed in the shot was stated to give good effects. The charge would be approx. 0.5 cc.

11. Ground contamination munitions

Work was started in 1930 with a 5 litre type of chemical mine and although the design was sealed production had not been carried out.

In 1939 the 10 L. Sp Bu 37 was designed and later put into large scale production.

The chargings were :-

- (a) ZOA (thickened mustard containing anthracene oil) double yellow ring.
- (b) OA (mustard containing anthracene oil) one yellow ring.

The idea of anthracene oil (R) as a constituent of mustard was borrowed from the Poles. It was thought the smell of mustard would be disguised by that of the anthracene oil, the method of use being to contaminate an area which the enemy wishes to cross leaving lanes contaminated with R only. These lanes would be known to ones own troops but not to the enemy. The drawback of adding R to mustard was that the dark colour made it more conspicuous.

It was stated that the average height to which the bomb is ejected before functioning is 20-30 m. giving a contaminated area approximately 50 m. in diameter.

Two modifications were being considered to this type of mine. The first was to shorten the outer case so that after discharge the tall empty case (i.e. the projector) would not act as a sign-post to advancing troops and indicate the area of contamination.

This also constituted a saving in metal.

Secondly, by modification of the ejection charge to 180 g. and emplacing the complete mine at an angle, it was hoped to achieve a range of 250 m. This obviously would need a lengthened delay unit in the projected body. Partially constructed mines adapted for electrical firing which may have been for trials at these longer ranges have been found.

Other methods of creating chemical barriers were tried out. One method was to pour mustard into a hole in the ground lined with paraffin wax, cover the top over and wait for the advancing enemy to break the crust. The main object was to permit friendly troops to occupy the area without any vapour danger.

A second method consisted of glass bulbs holding approximately 250 cc of mustard which were painted half yellow and half green. These were emplaced in shallow holes in the ground and lightly covered over if necessary (Boden Kugeln). It was stated that troops passing over an area mined with these Bodenkugeln broke 80 per cent of them. A number of these glass bulbs have been found packed in cardboard lined wooden boxes at Raubkammer.

As an improvisation, the effect of bursting an egg-grenade filled into the hollow base of a bottle containing mustard had been tried. The resulting contamination was widespread and there was a strong initial cloud effect.

It was further stated that trials had been carried out in jettisoning the chemical mine from mechanised vehicles, so that by means of a spike on the base of the mine, it stuck in an upright position and functioned correctly after a predetermined delay.

A chemical mine which acted like a concertina was being considered. The pressure of the foot ejected H from a nozzle into the air and it was hoped, onto the unsuspecting walker. The release of the pressure allowed a fresh amount of H to pass into the jet, ready for the next unwary passer by.

An experiment was in hand with a trip type of mine the Fl Ps. which had a delay fuze of 1-2 seconds operated by the passing tank. Then the container was ejected upwards and exploded at a height of 1-2 m. Trials were pending with the bomb charged incendiary material.

Trials with the U.S.A. type of chemical mine had showed it to be 75 per cent as effective as the Sp Bu 37.

12. Hollow charge weapons (Munroe Effect) using CW agents

After the attack on Fort Eben-Emael in Belgium in which penetration of the concrete was achieved by using hollow or shaped charges, research was started on the possibility of injecting CW agents by utilising the hollow charge principle.

The small smoke grenade No.42 which was a standard store when filled smoke, was used for experimental trials. CN was used in all the preliminary work which appears to have been of empirical nature. It was stated that the incorporation of a cone of 30° made from $\frac{3}{4}$ mm. steel permitted the No.42 grenade to penetrate 80 mm. or armour plate. Using this cone as the standard, a series of trials were carried out, in which rounds having CN disposed in various manners were used. The CN was placed in positions such as (a) the tip of the nose of the round, (b) various positions in the empty cone, (c) a lining to the cone in contact with the HE, (d) a solid lump embedded in the HE just below the apex of the cone.

These arrangements were first tried out to see whether the penetration performance had been impaired. Then chemical sampling was carried out after penetration of plate had been effected.

The general conclusion was that in all cases the heat of detonation and heat of the explosive jet were such that the CW agent was decomposed.

During interrogations there appeared to be no indication that a "follow-through" unit had been considered.

Research was next turned to static hollow charges and after exploratory trials it was found that the best penetration effect was obtained with cones made from the solid. The presence of a ridge, joint or unevenness of contour affected the "jet". The best position for insertion of CW agent was to attach a hemispherical nose and line it with the agent. It was stated that a lining of 15-25 g. of CN gave excellent results.

At this juncture, higher authority stepped in and ordered that standard HE hollow charge rounds should only be considered and the 75 mm. shell was therefore used for pilot trials. Promising results were obtained with rings of CN, Excelsior and Sarin absorbed in Keiselguhr, placed round the mouth of the cone, but in later trials results were variable. At this stage work ceased owing to military events.

13. Aircraft gas bombs

Research on the 250 kg. bomb was commenced about 1935 when the

first KC 250 bomb was designed and tried out. This bomb which was marked with one yellow and one green ring (Fig. XVII), was charged 100 kg. of O-lost, had a bursting charge of 15 Kg. of HE and was fitted with Fuze No.26. It gave a very poor performance only about 3000 were produced and filled.

By 1937 attention had been directed to an air burst 250 kg. bomb and this was tried out charged CN. The bomb has a small burster and was intended for summer or tropical use over woods. The height of burst aimed at was 100 m. and the necessity for an accurate fuze was realised. The fuze used was either 9 or 59A. This was the KC 250 W (two white rings) (Fig. XIX.). When burst at a height of 100 m. an area of 5000 m. was stated to be contaminated. The fuze was either 9 or 59A.

At the end of 1944 trials were carried out at Raubkammer using 250 KC II Gb bombs from stock with the following objects (a) To test stock munitions (b) To try out the air-burst bomb aiming tables (c) To determine the accuracy attainable by ordinary Luftwaffe pilots. Ju 88 aircraft were used, each carrying 8 bombs. Generally speaking the bombs were satisfactory, but in some cases the Zähllost was non-homogeneous, consisting of thick lumps in a thin liquid. The reason for this could not be traced; it occurred both with Tornosit and with Polystyrol and in bombs of all dates between 1939 and 1943; in all about 10% of the bombs had this fault. The Zähllost persisted on the ground for 8 - 14 days according to the height of release. The aiming tables were on the whole satisfactory and the aiming of the pilots good, but in many cases the wrong fuzes were used. 12 aircraft were used in these trials, and it was planned to repeat them with larger numbers in May 1945.

The opinion of the Luftwaffe had been that phosgene would be the most effective charging for bombs, and as the most useful size from the bomb stowage aspect was 250 kg., work was pursued on this bomb. A series of trials chiefly to ascertain the optimum case thickness for phosgene was carried out and eventually a wall thickness of 3 - 4 mm. was accepted. The burster was a small one located in the middle of the bomb and this bomb became KC 250 II Gr (1 or 2 green rings) (Fig XX). It was fuze No.55.

It had been realised that no satisfactory ground burst bomb charged mustard was available, due to the non-availability of a quick acting fuze. Accordingly the Green ring II bomb was modified in fuze design and activation by the incorporation of a nose striker which passed through a channel to the side fuze.

The HE content was also increased. This bomb charged mustard became the KC 250 Gb (1 yellow ring) (FIG. XXI). The fuze was No.26. It gave an effective contamination when ground burst over

an elliptical area of 600 m². Recently this bomb has given inflaming trouble.

The 250 KC III Gr (3 green rings) (Fig.XXII.) came into being in 1945 when empty bomb cases were used as storage and transport vessels for Tabun. The Luftwaffe had the bombs headfilled in case of need. They are stated to hold 83 kg. of Tabun and 4.6 kg. of HE. Trials with these bombs gave a lethal area (Ct = 300) of 2500-3000 m² and a disabling area (Ct = 200-250) of 10,000 m².

The assessment of Tabun was carried out by dropping a bomb and then positioning animals at zero plus 1 minute. Inflaming of Tabun occurred twice in 50 bombs but no assessment of the loss due to inflaming was made.

In 1944 redesign of the tail was carried out to enable bombs to be carried by high speed aircraft. The new design of tail which carried a large cylindrical drum was to have been used on bombs charged phosgene, mustard and Tabun. Also a new and faster fuze, the No.55A, was available.

The efficiency of the KC 250 II Gr (Phosgene) was again investigated and the burster was modified. Although the reason was not completely understood, results of trials showed that a long central burster extending to the nose of the bomb gave a much improved performance. The final decision was to use 1 kg. of HE extending the full length of the bomb using fuze DA 55. There was a move to reduce the burster to $\frac{1}{2}$ kg. but this was not approved.

The KC 250 III Gr bomb was also tried out charged mustard with the burster reduced from 4.6 kg. to 1.5 kg. but the results could not be ascertained.

In 1942 trials were commenced with 500 kg. bombs charged phosgene. The burster was 3.5 kg. TNT and the bomb was accepted for service but it is doubtful if any were even charged.

Trials were done in 1944 with 500 kg. bombs charged mustard with a burster of 1.5 kg. HE. The area of contamination, though heavier, was only slightly larger than that from the 250 kg. bomb.

The use of 1000 and 1800 kg. bombs charged phosgene was considered. Trials were carried out using a detector paper method of delineating the area subjected to a dosage of Ct = 1000. Two rows of animals were included and acted as checks on the adjacent papers. Details were not available and the only actual figures which it was possible to obtain for the effects from bombs charged phosgene were as follows :-

Munition	RESULTS			Remarks
	Concentration mg/m ³	Time in seconds	Distance in m downwind	
4 - KC 250 II Gr 400 kg phosgene	65,000	10	30	Performed to assess danger from Allied bombing of Germany with Phosgene bombs
1 - KC 1800 II Gr 750 kg Phosgene	32,000	10	30	

The following were given as the areas receiving a Ct of 1000 from phosgene bombs of various calibres.

250 kg.	4000 m ²
500 kg.	12000 m ²
1000 kg.	30000 m ²
1800 kg.	40000 m ²

These figures are for single bombs. It was stated that if a number of phosgene bombs are dropped in such a way as to reinforce one another, the effect is proportional to the weight of charging irrespective of the calibre of the bomb.

The 1800 kg. bomb was dived onto the target and released at 500 m. The bomb was stated to contain 750 kg. of phosgene and 12 kg. HE, and to give a concentration of 73 g./m³ in 1 minute at a distance of 30 m.

In 1945 trials were pursued with 250 kg. bombs charged AC which were to be known as KC 250 V Gr but inflaming troubles were

continuous. Various methods of preventing ignition of the charging were tried, such as the following :-

- (i) An inert surround of the burster.
- (ii) 20 per cent water in the AC.
- (iii) A surround of the burster with CCl_4 .
- (iv) Varying the explosive.

but none were very successful.

Just before work ceased they had done a trial with an air burst bomb charged Tabun and the view was held that this was the best method of using this agent if the height of burst could be kept low i.e. 30 - 100 m.

Bombs charged Sarin were to be known as IV Gr. Two trials had been carried out, suggesting that the lethal and disabling areas from a 250 KC bomb charged Sarin are 10,000 and 20,000 m^2 respectively.

14. Aircraft Spray Bombs

Because of the Luftwaffe's dislike of the low flying necessary for spraying, trials had been carried out with 500 kg. bombs charged thickened benzene which functioned as spray bombs after release from the aircraft.

It was stated that the aircraft dived and as it pulled out and commenced to climb again the bomb was released at a height of 20-30 m.

A slight delay in the ignition arrangement allowed the bomb to fall clear of the aircraft and then by means of rings of cordtex (Penta) holes were blown in each end of the bomb. Sited round the hole in the rear end were four igniters connected in parallel with the cordtex cutting charge.

It was stated that after release the bomb flew horizontally for 400-500 m. issuing flame. As the tail of the bomb was held in place by a central rod welded to the disc which is cut out of the bomb end, it seems very improbable that much level flight would be achieved. The tail must come off, before liquid can issue and this would result in a very unstable body. Also the only means to force out the charging is pressure generated by travel through the air.

Modifications were made to this bomb in order that liquid CW agents could be sprayed. Experimental models have been found which have an emission pipe running the length of the tail. The outlet was again opened by cutting off the welded-on cap with cordtex and internal pressure was applied by means of cordite or other suitable gas producer. Fuller details of this novel weapon will be given in a separate report after examination of the sample being sent to U.K.

15. Toxic Smoke Aircraft Bombs

A 50 kg. bomb holding 13 kg. of 50/50 DM/NC mixture was developed. The bomb acted, after dropping, as a static generator and in order to decrease burying the terminal velocity was reduced by a drag plate secured across the tail fins. The burial on soft ground was stated to be approximately $\frac{1}{2}$ m. The emission period was 4 minutes and the maximum concentration under favourable conditions at a distance of 25 m. was 500-1000 mg/m³. Large scale production of these bombs was carried out at Pommerschen Industrie Barth. This is the KC 50 II Bu (2 blue rings, Fig. XXIII.)

Trials were pending with a 250 kg. bomb of the same type. In one static trial a bomb containing 40 kg. of charging burned for 2-3 minutes and its effects were felt at a distance of 10 km.

16. Cluster Projectiles

The opinion in Prüf 9 was that small bombs charged gas would give a better performance than the larger sizes, and accordingly experimental work on clusters had been started.

The cluster case used was somewhat similar in appearance to the 250 kg. bomb but had a more rounded nose and was in two halves hinged at the nose. A time fuze opened the cluster and allowed the contents to scatter.

It was understood that consideration was also being given to a 500 kg. cluster.

Trials had been carried out with inner bombs charged screening smoke composition and DM/NC mixtures. These bombs were smoke generators adapted by the addition of half cylindrical tails equal to the length of the bomb. These tails which were perforated acted as destabilisers and increased the scatter. It was possible by packing bombs head to tail completely to fill the cluster, the half cylindrical tails nestling over the bomb bodies. This inner bomb was known as the K.B.3 and was believed to be manufactured at the Herman Goering Werks, Brunswick.

Consideration was being given to use of cardboard inner bombs to economise in steel. These had been tried experimentally, the bomb being known as K.B.10.

The opening height aimed at was 500 m. and it was found that from this height the 10 bombs from the 250 kg. or the 20 bombs from the 500 kg. cluster spread over an area of 80 m. x 40 m. under normal conditions. There was a tendency for the bombs to fall in two groups.

The toxic smoke generator bombs had impact igniters. Preliminary experimental work had commenced on a liquid charged bomb, the intention being to use a 340 g. TNT burster and a No.73 fuze.

A preliminary trial with a small bomb to work on the HE principle had been done using a DA fuze and a gunpowder charge, but failure had occurred owing to splitting.

As drawn steel tube of the required diameter was not available, they had endeavoured to strengthen the bomb with liners, but this also had failed.

There had been tentative experiments with a rubber cylindrical bomb charged with mustard gas. These were charged through a tube at one end of the bomb and were opened in the air by means of a length of cordtex running round the bomb. The initiating detonator had a delay incorporated which started when the cluster opened.

17. Fuzes for airburst aircraft bombs

Although the standard fuzes were used experimentally for air burst bombs, it was realised that they were insufficiently accurate. It was stated that the error in height of burst was about 20 per cent of the height of release.

There had been a request to the fuze experts for a fuze to give a height of burst of 50 - 150 m. above the ground. A radio fuze designed to function at 10 - 20 m. had been sent for trial; out of the 6 received, one failed and the remaining 5 functioned at the correct height.

A barometric fuze had been suggested and although it was understood that work on this design was being pursued, no fuzes ever arrived for trial.

Reference was made to the Italian fuze which was reputed to be actuated by a weight on a string, this leading the bomb during its fall. A few abortive trials were carried out, the usual result being a mass of tangled string and non-functioning of the bomb.

A telescope stick fuze which extended about 8 m. was found. Samples have been sent to the U.K. for examination and a separate report containing further details will be issued.

18. German spray apparatus

S.200. This spray apparatus has a volume of approximately 160 litres and is pressure operated. It has a bulbous nose tapering towards the rear. The compressed air bottle is housed in a tube welded to the rear end of and extending forward into the body of the apparatus. Valves and connecting pipes are covered by a tail fairing and the emission pipe is taken from the front and bent round to point to the rear parallel to the axis of the body. It is designed for use with either smoke or gas.

When used for smoke the apparatus is fitted with a solenoid operated valve, which is remote controlled from the pilot's cockpit and can be used for intermittent emission. The size of the orifice on the Mk.VI type of valve is approx. $\frac{7}{8}$ inch and it is claimed that a smoke screen from 5 to 9 kilometres long can be put down by an aircraft flying at 360 km/hour and about 50 metres high. The smoke liquid used was stated to be 50/50 SO_3 -Chlorosulphonic acid.

When intended for use with gas, the solenoid valve was removed making the outlet approximately 2 inches bore.

S.500. This is a gravity type apparatus the design of which is based on captured Russian VAP 500 spray apparatus. The volume is about 350 litres and the time of emission approximately 4 seconds. Experiments had been carried out with four S.500 mounted on a Junkers 88, between the engine nacelles, charged AC and all four functioned simultaneously. The total time of emission was approximately 5 seconds. Results of these trials appear in Appendix III of this report. It was stated that this apparatus was preferred to the S.200. Samples of the S.500 are available for trial.

S.250. This was a new spray apparatus under development by the Germans, for carriage on the F.W.190. It was on the same principle as the Russian, but of a more convenient shape and smaller, the volume being from 160-180 litres. The control of the emission orifice was to be electric, as some trouble had been experienced by the Germans with the mechanical control of the Russian apparatus.

The air space allowed for chargings was 6 per cent, climatic storage trials up to 60°C having proved this satisfactory.

The spraying trials carried out were not of a highly developed nature, and in the case of mustard gas, regard was paid only to the

weight of contamination delivered and not to drop size and distribution (see Appendix I). It was thought that no effect through clothing would be obtainable at heights greater than 50 m.

The Luftwaffe it appeared was not favourably inclined to the use of spray owing to a dislike for the flying tactics involved.

19. Future research on Aircraft weapons

It was stated that the following would have been the future programme of research and development on aircraft weapons.

- (a) Use of larger bombs charged phosgene.
- (b) Modification of size and position of bursters particularly for bombs used under winter conditions.
- (c) Development of clusters with a view to obtaining optimum height of opening.
- (d) Trials with bombs charged with mustard thickened with Polystyrol 3.
- (e) Prevention of ignition of mustard chargings.
- (f) Ballistics of 250 kg. bomb for air burst.
- (g) Continuation of development of cluster bombs.
- (h) Design of a 50 kg. bomb for Tabun and Sarin.
- (i) Use of high altitude sprays.
- (j) Spraying of Tabun.

20. Thickening agents

The Germans used thickeners in C.W. liquids primarily to increase persistence, and not to prevent shatter on ejection from an air opened munition. The viscosity favoured was very high, of the order of hundreds of poises.

Tornesit (To), a chlorinated rubber, was the standard thickener, used in conjunction with S-Wachs, a synthetic wax resembling bees-wax prepared by I.G. The following were standard chargings :-

Z-OA 396	91% OA	6% tornesit	3% S-Wachs
Z-OM 462	89% OM	8% tornesit	3% S-Wachs

Owing to supply difficulties, substitutes for tornesit were sought. The following, in order of preference were considered the best of the many substances tested :-

Polystyrol III (not highly polymerised)
plus polyacrylonitrile.
Polytetrahydrofurane
Polyvinylchloride
Polyvinylacetate
Acronal I (polyacrylic acid)

Polystyrol III alone gave a very viscous sticky mixture, but this was reduced in stickiness by adding other substances such as Polyvinylchloride, Polyvinylacetate or S-Wachs.

For future use the following mixtures were envisaged :-

Z-OA 909 = 92% OA, 5% Polystyrol III, 3% S-Wachs

Z-OA 973 = 85% OA, 12% Polystyrol III, 3% S-Wachs

Z-OA 974 = 82% OA, 15% Polystyrol III, 3% S-Wachs

Z-OM 832 = 90% OM, 7% Polystyrol III, 3% S-Wachs

Z-OM 977 = 85% OM, 12% Polystyrol III, 3% S-Wachs

Z-OM 978 = 82% OM, 15% Polystyrol III, 3% S-Wachs

Polymethymethacrylate was among the substances tested, but it was rejected on account of low solubility.

21. Impregnated Dusts

Investigation had been made at VIAL, Spandau of the dispersion of non-volatile vesicants using a fine dust as the carrier following information that the French considered that a 10-fold gain in vesicancy was thus obtained. About 100 different kinds of carriers had been tried. Of these Frankonite and Tonerdeger had been found the best and after further experiments, Tonerdeger was selected for the main experiments with vesicants.

Frankonite is a prepared Fuller's earth. For the purpose of the investigation it was ground in a small vibrating porcelain ball mill and by this means a particle size range of from 10 to 0.1 microns was obtained.

Tonerdeger is a precipitated aluminium hydroxide which is sufficiently fine not to require any grinding. It is prepared from

bauxite by dissolving in sulphuric acid and treating with sodium carbonate. Winter, Fährbrücke, nr. Zwickau is the manufacturer. When impregnated with N-lost in a 50/50 ratio it still remains a dry powder. Frankonite on the other hand can only be used in a 60/40 ratio. Di-chlor benzene was used as a harmless simulant in the preliminary experiments.

The vesicants tried with Tonerdeger were "double omega" (Dopple Omega) or sesqui-mustard, B-stoff which is the same as T.724, and N-lost. Tabun was also considered, but it is too unstable for use in this manner.

For animal and human experiments in the laboratory, the impregnated dust was blown from a $\frac{1}{2}$ to 1 litre container by compressed air into a 100 m³ chamber. From 20-30 per cent, rising to 50 per cent in high concentrations, fell out of the cloud to the floor of the chamber. Concentrations of 15 - 800 mg/m³ were tried. Micro-examination of the particles which settled on the glass slides were made, and samples were also taken in two Kolliker flasks in series at a flow rate of 40 L/min. and the deposit analysed chemically for the vesicant. The moving film (Kineograph) method was also used, but it was not very successful and was discontinued. (Apparently this method had been developed by Dr. Zeuner of Fl₄, assisted by Dr. Leopold.). The method was not in high repute.

Experiments were made on mice, dogs and cats. The Ct for 100 per cent deaths for sprayed N-lost was stated to be 800-1000 mg.min.per m³, whereas it was reduced to 300 for a high concentration of dust impregnated with this agent. The Physiological aspects had been supervised by Dr. Böttger of VII L (later V b L). The bodies and heads of the animals were covered so that the effects were mainly due to inhalation. Eye effects were small.

Experiments were made on the vesicant effects on man. Usually the concentration was 500 mg/m³. The observers exposed the lower parts of their arm to the cloud for 10 minutes. Vesication was produced. It was considered that double omega was ten times, and B-stoff five times, as vesicant as N-lost.

Attempts were made to penetrate particulate filters by means of this dust, but, not surprisingly, without success. Clogging experiments were also made with a similar lack of success.

Dust retention experiments were carried out on human observers using a radioactive tracer, Thorium x, as the indicator. Retention by the lungs was some 80 per cent.

For bursting chamber and field work, the impregnated dust was compressed into cylindrical blocks, about 1 ft. length and 6 in. diameter, at a pressure of about 200 kg/cm², a hole being formed down the centre for the explosive. The explosive was nitro-penta, at the rate of 200 g. per 2 kg. of compressed dust. It was intended to wrap the cylinders in paper and pack them in a cluster bomb (Zerleger Bombs). When exploded, these cylinders were only about 40 per cent efficient. Animal experiments were tried in the chamber with similar results to the laboratory chamber experiments.

The powder was also emitted from the S.500 spray tank, but the results were disappointing.

Investigation had been made of the defensive use of these impregnated dusts. The dust was spread on roads and qualitative experiments made to see how long the dust remained on the surface and how it behaved when cars passed over it. The dust persisted for a long time and was thought to be highly effective. On the strength of these experiments, 1000 tons of Tonerdeger were ordered, but the material was never impregnated. B-stoff would have been the impregnating agent.

Floating dusts and dust blown from fans were not successful. Tabun was found to be destroyed by the carrier.

The apparatus and press used in the experiments were brought to Raubkammer early this year and were inspected in Haus F and Haus P of R VI. A sample of Tonerdeger was taken.

22. Group X of Wa Prüf 9

The work of this group can conveniently be dealt with at this point as they dealt mainly with some of the munitions aspects of Chemical Warfare.

As no members of Group X were present to be interrogated only an indication of the work of this group can be given. The laboratory work for this group was done by F4, Spandau.

Group X were responsible for the production of incendiary materials except oils for flame-throwers which was the responsibility of Wa Prüf 5. Before autumn 1942 Wa Prüf 1 had been responsible for the development of incendiary materials, but up to 1941 there had been no operational requirement. With the advent of the Russian campaign, however, and the probable necessity for the attack of wooden buildings Prüf 1 produced the phosphorus incendiary bomb. After Group X took over the first requirement was for a substitute for the phosphorus incendiary bomb due to the large requirements of

industry and the factory at Dyherenfurth. Experiments were carried out with thermite mixture and with mixtures of thickened oil with cellulose, textile substitutes, bast, waste etc., but as far as is known none of these mixtures was introduced into the service.

Another requirement was for a substitute for phosphorus in practice weapons and for this $AlCl_3$, NH_4Cl , and compressed pellets of white Fuller's earth, alumina or silica gel were suggested. The last mentioned substance appears to have been quite a good substitute giving rise to a white cloud on bursting.

Asked by Prüf 1 to improve the incendiary effect of the anti-tank shell, the addition of 20-30% of Al to the explosive was suggested and eventually introduced. Attempts to incorporate sodium-potassium alloy showed no improvement.

In the autumn of 1942 an examination of spontaneously inflammable substances was undertaken. The first substance used was S charcoal a pyrophoric charcoal which glows in half a minute on exposure to the air and is prepared by the I.G. (Leverkuisen?). It was used in the larger calibre mortar bombs and in the 32 Wurfkorper Flam. It was found in Russia that over 50 per cent of the 32 Wurfkorper Flam did not burn at all and many others did not burn well. The cause of this was traced back to the fact that the filling was being continually changed due to the use of other substitutes and the S charcoal was not capable of igniting these substitute fillings. Organic silicon compounds were tried as well as sodium, potassium and zinc ethyl, but the most effective substance was found to be phenyl sodium and this was eventually filled into some shell.

There was also a requirement for an incendiary projectile for the Russian campaign to set large expanses of reeds on fire. The Sprühbuchse filled with a mixture of thickened oil and cellulose or nitrated cellulose and ignited by means of S charcoal or phenyl sodium was fired at an angle of 45° . This did well in reeds, but if it fell in water it went out. For a filling which would also burn on water a petrol-benzene-Diesel oil mixture was used.

Experiments on floating oil on the sea and igniting it as a defensive measure had been tried on the Albanian coast. The ignition of this oil film was simple as long as the film remained near the coast, but if the film was washed away from the coast it became much more difficult. This problem was also raised in connection with the coast of France before the invasion. As these thin films of oil on water are rapidly cooled and thick films are impossible to obtain it is not believed that experiments were carried further.

From papers captured at Le Bouchet and from other intelligence sources it was learned that it was possible in U.S.A. and Britain to produce by bombs and rockets and possibly even by aircraft spray a flame barrier one and one half metres high which burned for several hours. In Le Bouchet they found pulverised active charcoal soaked with petrol-benzene, CS_2 -benzene-Diesel oil, ether-benzene-Diesel oil and other mixtures. Group X carried out many experiments with pulverised active charcoal soaked in such mixtures and filled into bombs, but only got an instantaneous flash. When small cylinders of active charcoal soaked in such mixtures were used a fire was produced up to 15 to 25 metres round the bomb and lasted for 2 minutes. Further news from Britain instigated experiments with CaC_2 dust and later with metaldehyde and petrol until in February 1945 it was finally concluded that it would be impossible to produce a flame lasting for 2 hours by such means.

Group X were also responsible for producing protective materials against fire and one particular requirement was to protect the wooden bridges in Russia which were being attacked with incendiaries from Russian aircraft. German industry was no longer in a position to supply the normal protective materials and a paste of MgCl_2 and clay was suggested.

An adhesive substance to attach hollow charges to the surface of tanks etc. was another requirement. It was difficult to find one suitable for both summer and winter, but eventually two plastic adhesives were developed by I.G. one for summer and one for winter. These usually stuck well unless the tank was very dusty or very wet.

Group X were also studying substances which could be used in the field to attack the internal combustion engine. Many suggestions for this purpose were found at Le Bouchet, such as oxides of chlorine, aluminium powder, silicon powder, acetylene, and nitroethylene, but none of them were found to be of any use. The best results were eventually obtained by the use of ethyl fluoroacetate which attacks the oil film and allows the metal to corrode, but in the field it would be a long time before any noticeable effect could be obtained by this method. At least 0.2 per cent of ethyl fluoroacetate is required in the oil.

Important industrial premises were to be protected by means of a grenade filled liquid CN which would function when the wire fence was cut as well as Spruhbuchsen attached to trop wires. Hand grenades filled with CN solution would be given to the guards. It was also considered that the guards might be given glass balls filled with either a dye which would not wash out or a colourless substance which would fluoresce in ultra-violet light. Rooms

containing top-secret documents were to be protected by means of containers filled with (1) a substance which would give a loud report to attract the guard. (2) a pyrotechnic substance which would develop flame in a short time or (3) an instant lachrymator.

In 1943 files were found in Russia on the use of smoke rings and shortly afterwards a certain Professor Tokmatscheff came over to the Germans and also suggested this as a method of dispersing gas. It was suggested that if a pear-shaped tin-plate vessel was fitted to the mouth of a machine-gun smoke-rings with a speed of 120 m/sec. were formed and that these could disturb cardboard targets at a considerable distance.

Professor Tokmatscheff claimed that if chlorine or ammonia were introduced into the pear-shaped chamber it was possible to detect these gases at a distance of 300 metres. By using a 7.5 cm. gun he claimed to be able to get the smoke-ring effect to a distance of 1000 metres and also by using bulbs of a different shape to be able to send the smoke-ring round a corner.

Group X carried out one test of this method and decided that in order to send a smoke-ring a distance of 1000 metres it would be necessary to have a bulb $1\frac{1}{2}$ to 2 metres long and 2 metre diameter and that even then the ring would start to dissolve appreciably after the first 100 metres.

In the autumn of 1939 a suggestion was made by a Pioneer officer that air-gas mixtures might be used for exploding underground fortifications. The plan was to bore down below the fortifications from a distance of about 100 metres, burst the concrete floor by means of an explosive charge and then introduce an explosive gas mixture such as hydrogen-air, carbon monoxide-air etc. which could be set off by means of a thermite cartridge. Alternatively a hole could be blown above ground if this were possible by means of a hollow charge and a tube placed through the hole for the introduction of the gas mixture.

The first trials were carried out in the summer of 1940 on the Czecho-Slovak fortifications. It was found that of the first gases tried methane, hydrogen and carbon monoxide the air-carbon monoxide mixture was the best. It was necessary to have some idea of the size of the chamber into which the gas was to be introduced so as to be able as far as possible to produce the optimum explosive mixture and it was found that carbon monoxide allowed the biggest margin of error.

There was one drawback to the use of carbon monoxide, however, it was a poisonous gas and the use of carbon monoxide in this manner would have meant the initiation of Chemical

Warfare. It was therefore decided to search for another non-poisonous gas which could be used in a similar manner as long as there was no Chemical Warfare. The most satisfactory gas for this purpose was found to be ethylene after a long series of trials begun in 1940 and finished in 1943. The final trials were carried out at Lembach and Katenhofen on the Maginot line and the Pioneers worked out an efficient method of relaying up the large quantities required. It is believed that use was made of air-ethylene explosive mixtures with good results during the fighting in Warsaw in 1944 in order to blow up the Warsaw drains. There seems to be no doubt, however, that if gas warfare had started the carbon monoxide-air mixture would have been preferred. The ethylene-air mixture is more suitable for smaller fortifications and it is necessary to know fairly exactly the size of the chamber for the explosion. Experiments showed that animals died from the effect of the detonation and measurements showed pressures of 30 atmospheres and temperatures of 80-90°C.

It had been learned through intelligence sources that U.S.A. intended using similar methods and also explosive dusts. Experiments were to have been carried out by VIaL and Group X on the use of coal and sugar dust, but the work had only just started. Preliminary work with liquids such as ether and acetone had given less satisfactory results than with gases.

Group X were also responsible for developing field trial technique, but this was considered to have reached such a high standard that no work had been done since 1944.

The head of Group X, Dr. Stantion, had a personal interest in work on insecticides, although this was not included in the official functions of the group. His interests lay mainly in the apparatus used for disseminating the agents. This work was co-ordinated by Dr. Beyer of OKW/Wiss, who is the most competent to give full information on the subject. The research was apparently complex and was carried out in various forestry institutes. Strassburg was the main centre. The work was almost entirely directed against the Colorado beetle.

23. Miscellaneous information on Chemical Munitions

The following paragraphs give some information on various miscellaneous subjects connected with chemical munitions or the offensive aspect of chemical warfare.

No work appears to have been carried out at Raubkammer on the subject of anti-personnel incendiary weapons. The general opinion was that it has an effect on morale only and after its first use is easily countered.

A good deal of work had however been done on chlorine trifluoride which was known as N-Stoff as an incendiary agent.

A factory for the manufacture of ClF_3 costing 100 million RM was built at Falkenhagen, Frankfurt-on-Oder, on the recommendation of Prof. Schumann of Wa.F. After the factory had been built and a production output of 50 tons per month had been reached, it was realized that, owing to lack of co-ordination of effort, no one had a clear idea as to how the material was to be used in the field. Prüf 9 were asked to carry out experiments on its offensive use as an incendiary agent with particular reference to the attack on respirators. Laboratory experiments showed that it was quite useless for this purpose, some 80 g. being required to set fire to a filter. Wa.F. were not satisfied with the results and a field trial in which 300 x 15 cm. rounds containing in all 1,200 kg. of charging were fired over a close lay-out of all kinds of inflammable materials including dummies dressed in normal clothing. Nothing of note was achieved; the clothing of the dummies did not catch fire although one had a direct hit and the temperature rise inside containers through which air was drawn was only 2°C . Next, a 500 kg. bomb was burst $1\frac{1}{2}$ m. from the entrance to a room filter, but again without appreciable effect. Only if the ClF_3 were sprayed in very high concentration and 4 or 5 litres drawn through a container held near the source could the contents be induced to inflame. It was then realised that the ClF_3 rapidly hydrolysed in the air to form HCl and HF and incendiary effects at a distance were not to be expected.

As a result of these experiments, the production was reduced to 10 tons per month and the control of the plant passed to the S.S. under Dr. Schwab. Its eventual fate is unknown.

There appears to be no support for the statement that Fort Eben Emael in Belgium was captured by the Germans in 1940 by squirting ClF_3 into the intakes of the filtration units. All the evidence so far has shown that German paratroops landed on the forts and put them out of action with hollow charges.

Some experimental work had been carried out on the introduction of gases into narrow openings by means of a hand spray of 5-10 litres capacity. The weapon proposed had to be actually introduced into the opening, and there was no question of any attack being made from a distance. The gases considered were lachrymators, hydrogen cyanide, cyanogen chloride, mustard and chlorine trifluoride. It was hoped with the first two that filters could be penetrated. The weapon was abandoned as it did not appeal to the pioneer formations for whose use it was intended.

Floating mustard had been tried as a means of protecting

beaches, but was not successful owing to the case which rough water destroyed or removed the film. Of the many substances tried, including calcium carbide, brown coal dust was considered to be the best flotation agent.

When a new machine gun with a rate of fire of 1400 - 2000 rounds per minute was approaching completion, work was started on experimental C.W. ammunition for it, with the object of attacking tanks by creating a concentration of gas round the air inlets. AC was found to be useless on account of inflaming, but Tabun and Sarin were considered interesting possibilities, although no work was actually done on these. Excelsior was tried once, with a small amount of ammunition and gave good results. Smoke was tried but was found useless against a moving tank. The work was abandoned because of production difficulties.

The Germans believed the Russians to be interested in iron and nickel carbonyls, but the former did not consider that the carbonyls had any offensive possibilities. They had investigated a report that the French had found carbon monoxide in solution in ammonia, amines etc. to be of value, but the Germans considered it impossible to use carbon monoxide in this way.

The Germans thought Russians intended to use finely divided calcium cyanide which the Germans tested and found to be nearly as good as AC itself. From a good American intelligence source they knew the Americans had introduced as a filling $\text{Ca}(\text{CN})_2 \cdot 2\text{HCN}$. This complex was prepared but they found it not very effective and therefore believed they had obtained the wrong substance.

On receipt of intelligence information that the Russians and British intended to spray concentrated acids and alkalies, experimental work on this subject was initiated. Of the substances tried sodium hydroxide was considered useless, but fuming nitric acid was thought to be of some value in a low spray owing to the painful burns produced.

Plans were in hand to fill the V1 (Gerat 024/B) with phosgene in place of the normal 800 kg. of hexa-TNT. One experiment at Raubkammer at rest gave an effect similar to that from a 1000 kg. bomb. It was also planned to use the war-head as a cluster bomb holding 200 K.W.3. Blue Ring II charged and declustered 200-300 metres before landing. No suitable time-fuze had been developed however, and no trials had been carried out.

No plans had been considered for using gas in the V2 (Gerat A/4). If gas warfare had started however, Prüf 9 would have recommended consideration of a charging of 2500 kg. phosgene, but not of clusters of small bombs. Prüf 9 had heard rumours of a still

larger V weapon which contained 6000 kg. of explosive, but knew nothing beyond this. They would, however, have considered phosgene an eminently suitable charging for such a weapon.

The Russians were reported to have a white ring and blue ring filling for 10 kg. anti-personnel bombs, and accordingly some work on a German version was undertaken. A cardboard container holding 200 gms. CN (or a mixture of Clark I and Clark II) mixed with HE was introduced into the bomb. Preliminary trials gave promising results and production was under consideration.

The inclusion of a small quantity of CN in the tail of an HE bomb was considered, but the results were not promising.

Foreign spray mixtures were said to be :-

U.S.A.	-	50 per cent - H
		15 per cent - H sulphone
		10 per cent - brom H
		25 per cent - Lewisite
Russia	-	21 per cent - H
		50 per cent - Lewisite.
		29 per cent - Intermediate products and impurities.

Another reputed American mixture was 10% of phenyl or ethyl arsenedichloride, 20 per cent nitrogen mustard hydrochloride and 70% mustard. The Germans considered that the decontamination of the nitrogen mustard constituent would be very difficult.

The Germans managed with difficulty to make sufficient of the reputed American spray mixture to determine its vesicancy, but not enough for field trials.

24. Marking of German Chemical Munitions

By interrogation of German personnel, and by the examination of the contents and construction of ammunition found in the Munster area, it has been possible to compile the following information on the system of marking used for German chemical munition. We are indebted to the 1st Canadian C.W. laboratory for sectioning and analysing the contents of the weapons found, and for providing a draft of the following text. Whilst it should be noted that the figures which are referred to are diagrammatic only, and that the information is subject to amendment as further samples of the ammunition are examined, it is believed that this information is substantially correct.

The basic colour of German chemical ammunition is the normal field-grey. The nature, effect and contents of a chemical shell is indicated by coloured rings on ogive and base, as well as various painted, stencilled or stamped numbers and letters. When the significance of all the markings is understood it is possible to tell, for any shell, the exact chemical and HE filling, as well as the design of the shell and the effect to be expected.

The coloured rings on the ogive and on the base are yellow, green, blue or white, indicating the physiological effect of the charging in the form in which it is dispersed.

Yellow	-	{Gelb - Gb}	Vesicant effect
Green	-	{Grün - Gr}	Choking or systemic effect
Blue	-	{Blau - Bu}	Stermutatory effect
White	-	{Weiss - W}	Lachrymatory effect

Associated with the coloured ring may be the number 1, 2 or 3, of the same colour, which distinguish the different chargings having similar physiological effects but which may have different degrees of effectiveness. It should be noted that the colour band is not necessarily a guide to the charging. For instance, mustard may be found in either yellow ring or green ring shell; in the latter case with a large burster giving an initial cloud of vapour and droplets and little persistent vesicant effect. A later development, the Green ring Yellow shell, is discussed below.

The latest information on the banding and contents of chemical shell is as follows, all having been confirmed by examination except Double Yellow ring and Blue ring 2 which have not yet been found

Yellow ring	-	Mustard gas, small burster
Double Yellow ring	-	Thickened mustard gas, small burster
Green ring	-	Mustard gas, medium burster
Green ring 1	-	Nitrogen mustard, large burster
Green ring 3	-	Tabun, head burster
Green ring Yellow	-	Mustard gas, large burster
Blue ring 1	-	DM with exterior burster
Blue ring 2	-	DA in Arsenöl, central burster
Blue ring 3	-	DM, base ejection generator
White ring	-	CN/HE intimate mixture

Six types of chemical shell had been accepted for service. The markings which identify each type are stamped on in the same colour as the identification ring of the shell.

- (a) The earlier type of ground contamination shell has a long narrow central burster tube (filled HE/Wax 60:40) and is always marked Gb. G/B. The "Gb" stands for Yellow

ring gas (Gelbring Kampfstoff), the "G" for ground contamination (Gelandebelagung) and the "B" is the code letter for the chemical filling (see below). A negative characteristic of this type of shell is the absence of any large coloured number just above the driving band (see (c), (d) and (f) below). There are two shell and one mortar bomb of this nature.

10.5 cm F H Gr Gelbring (mustard gas) (Fig.III).
 15 cm Gr 19 Gelbring (mustard gas) (Fig.IV).
 10 cm Wgr 35 St Gelbring (mustard gas) (Fig.XVI).

- (b) Differing from the above type only in the amount of HE in the burster tube (it is not so highly diluted with wax) is the earlier type of Green ring (initial cloud" shell marked Gb L/O (in green). Again the "Gb" represents Yellow ring gas (vesicant) but the fact it is dissipated as a cloud by the heavier burster is indicated by the letter "L" (Luftkampfstoff - an air-borne gas). The last letter "O" is again the code letter for the CW filling. Two shell only of this nature exist.

10.5 cm F H Gr Grünring (mustard gas) (Fig.I.)
 15 cm Gr 19 Grünring (mustard gas) (Fig.II.)

- (c) The new type of ground contamination shell which has a head burster, having a plate between the HE and CW filling, is known as the "Zwischenboden" (separating plate) shell. It is identified by the large coloured number 39 just above the driving band, representing the year of design of this body type.

10.5 cm F H Gr 39 Gelbring (mustard gas) (Fig.VI.)
 15 cm Gr 39 Gelbring (mustard gas) (Fig.VII.)

In addition, the Type 39 shell is also filled as Green ring 3 the Germans having found that there was less decomposition of the Tabun filling with a head burster than with a central burster.

10.5 cm F H Gr 39 Grünring 3 (Tabun) (Fig.X.)
 15 cm Gr 39 Grünring 3 (Tabun)

- (d) In order to produce a completely "initial cloud" or choking gas effect with vesicants the Type 38 shell was developed. This shell has a very large burster (weiter Kammerhülse - wide burster) relative to its size and is marked with the number 38, the year of design of this body type, just above the driving band. (In certain 15

cm. rockets the 38 may be replaced by the abbreviation "wKh".)

10.5 cm F H Gr 38 Grünring-Gelb (mustard gas) (FIG.V.)
10.5 cm F H Gr 38 Grünring 1 (nitrogen mustard (FIG.VIII.)
15 cm Gr 38 Grünring 1 (nitrogen mustard (FIG.IX.)

- (e) A fifth design is used for the solid HE/CW chargings of the White ring and Blue ring 1 types. There are no special markings to distinguish shell of this nature, except that the threaded-on base plate has in it two holes for the insertion of a two pin spanner.

7.5 cm Jgr 18 Weissring (CN) (FIG.XXIV).
10 cm Gr 19 Blauring 1 (DM)
10 cm Gr 19 Weissring (CN)
10.5 cm F H Gr Blauring 1 (DM) (FIG.XIII).
10.5 cm F H Gr Weissring (CN) (FIG.XI).
15 cm Gr 19 Blauring 1 (DM) (FIG.XIV).
15 cm Gr 19 Weissring (CN) (FIG.XII).

- (f) The latest design is the Type 40 base ejection (AB - Ausstossbuchse) generator shell, marked 40 and Bu L/M in blue. "Bu" indicates a Blue ring gas, "L" that it is a cloud gas (Luftkampfstoff) and "M" is the code letter for the filling. Also stencilled in black on the side near the base is 40 AB.

10.5 cm F H Gr 40 Blauring 3 (DM) (Fig.XV).

On each shell (and mortar bomb, rocket or aircraft bomb with CW filling) is a code letter, the same colour as the rings, which indicates the exact nature of the chemical filling. This letter is sometimes by itself but may be combined with other letters and numbers, e.g.:-

Gb	GA	K	O	F-6184
G/B	39	wKh	38	

In these examples the code letters are B, GA, M, K, O and F respectively. On bombs and occasionally on shell the code letter is painted in black. The code, taken from a captured microfilm, and complete to 1st January 1945, is as follows :-

A - Chloroacetophenone
B - Thiodiglycol mustard-Arsinol, 1:1 (Winterlost)
C - Thiodiglycol mustard-Chlorobenzol, 4:1 (Winterlost)
D - Thickened mustard (made from B)
E - Thickened mustard (made from a mixture of homologous mustards)
F - Phosgene

- G - Tabun
- GA - Tabun with 20 per cent Chlorobenzol (also Ga)
- H - Diphosgene
- K - Nitrogen mustard
- L - Thiodiglycol mustard - Anthracenol,
2:1 (Winterlost)
- M - DM or DM with DA
- N - DA in Arsinol, 40:60
- O - Thiodiglycol mustard (Summerlost)
- P - Hydrogen cyanide

There is a code number to indicate the nature of the HE burster. This is always a black number just above or below the colour ring on the ogive. In the case of the White ring and Blue ring 1 shell the number refers to the whole CW/HE insert. The code number does not refer to the size or shape of the bursting charge but only to the identity of the explosive used. Thus the same code number, 37, is used to indicate the head burster of both the 10.5 and 15 cm Type 39 shells. The list of bursters, where they are used and their general description is as follows :-

- 37 - The head burster of the 10.5 and 15 cm Yellow ring 39 shell. (PETN/Wax 60/40)
- 36/38 - The small burster in the earlier type Yellow ring ground contamination 10.5 and 15 cm shell and the 10 cm Yellow ring mortar bomb.
(PETN/Wax - 60/40)
- 32 - The medium burster in the 10.5 and 15 cm Green ring shell. This number is also used to indicate the relatively heavy burster in the 15 cm Green ring Yellow and Green ring 1 rockets, presumably because they are thin case weapons and need less explosive than a shell to gain the same effect.
(Petr/Wax - 95/5)
- 91 - The heavy burster in the Type 38 shell, 10.5 cm Green ring Yellow and 10.5 cm and 15 cm Green ring 1. (RDX/Wax - 95/5)
- 36 - CW/HE insert in the 15 cm Blue ring 1
- 46 or 46A - CW/HE insert in the 10.5 cm Blue ring 1
- 45 - CW/HE insert in the 10.5 cm White ring.

It has been mentioned that the base of the shell also has a corresponding coloured ring and the numerals 1, 2 or 3 outside of the ring if applicable. In addition, the name of the shell, the name of the fuze, the weight classification and the indication of the nature of the driving band all may be superimposed, in black or white, on the coloured ring.

Detector paint, applied to the welds and filling plug, may be pink, brown or yellowish-green in colour and must not be confused with the colour coding of the shell. For instance, in the Green ring 3 shell a bank of greenish-yellow detector paint occurs on the ogival weld immediately below the green ring and this has, in the past, given rise to some confusion.

Other markings on chemical shell, but of no CW significance, are the weight classifications (large Roman numerals I, II, III and IV) and the letters indicating the nature of the driving band (FES in white or KPS in red). These, of course, vary on different shell of the same type.

The Germans who have been interrogated have not produced a satisfactory explanation for the Green ring Yellow marking except to say that, although primarily producing a cloud effect, this shell may also have a vesicant effect. However, as the Green ring Yellow shell is the chronological successor to Green ring and has a far larger burster the fact is that a Green ring Yellow shell normally will have an even smaller vesicant effect than the Green Ring. A possible explanation is that the yellow ring has been added to indicate that the shell is a potential source of a vesicant effect should it become a leaker or break up after failure to detonate and, being a recent development, has not yet been extended to cover the case of the Green ring 1 shell which also contains a vesicant.

The only available German explanation of the relative meanings of 1, 2 and 3 ring markings is that the higher number indicates greater persistency. While this explanation holds for Yellow ring and Double Yellow ring it is not a satisfactory explanation for the differences between the different Green ring and Blue ring chargings. A more logical explanation would seem to be that the higher the number the later the development and therefore the better the gas or the better the effect produced. Certainly Tabun (Green ring 3) was produced later and was considered a better gas than HN-3 (Green ring 1) and also the Blue ring 3 shell is a later development and a more effective method for the dissemination of DM than is the Blue ring 1 shell. In this respect it is noteworthy that it was the intention to allot four green rings to AC and five green rings to Sarin.

15 cm Rocket Ammunition

These rounds are marked in exactly the same manner as shell. Three kinds have been examined and a fourth may exist. They are of two types, small burster for ground contamination and large burster for choking effect.

Small burster:

15 cm Wgr. 41 Gelbring (mustard)

Large burster:

15 cm Wgr. 41 w. Kh. Grünring-Gelb (mustard)

15 cm Wgr. 41 w. Kh. Grünring 1 (nitrogen mustard)

Not yet examined:

15 cm Wgr. 41 w. Kh. Grünring 3 (Tabun)

Aircraft Bombs

The standard German aircraft gas bomb, KC 250 Kg (Kampfstoff Cylinderische), is a modification of the 250 Kg. SC (thin case) type HE bomb. In addition there is a specially designed 50 Kg Blue ring bomb. It is known that trials have been carried out with 500, 1000 and 1800 Kg bombs filled various chargings but except for a few 500 Kg White ring and Green ring very few of these have reached the storage dumps.

The markings on bombs are somewhat confusing and appear to be unsystematic. They are named according to weight and ring colour, e.g. KC 250 III Gr which is a 250 Kg gas bomb with three green rings, green indicating that the contents have a choking or systemic effect. The Roman numeral after the weight should indicate the number of rings except when there is one ring when no numeral is used but there are nearly as many exceptions as agreements to this rule. Thus the KC 250 W has two white rings while most of the KC 250 II Gr bombs have only one green ring.

The overall colour of bombs is usually field-grey but may be buff. The rings are (usually) painted both on the nose and near the tail while the name of the bomb is in the centre. All markings on the bombs (except the colour rings) are in black and, in addition to the name, there is recorded the weight e.g. 166 Kg, the chemical filling code letter and design number e.g. G-6187, the number of the fuze (in a small circle) e.g. (55) and the code number for the HE filling and its weight e.g. 14 - 3.2 Kg (14 indicates TNT and is the commonest filling).

The following bombs exist in munition dumps in considerable quantities.

KC 250 Gb	-	(1 yellow ring) mustard (Fig.XXI.)
KC 250 II Gb	-	(2 yellow rings) thickened mustard (Fig.XIX.)

KC 250 Gr	-	(1 yellow, 1 green) mustard; larger burster. (Fig.XVII)
KC 250 II Gr	-	(1 or 2 green rings) phosgene. (Fig.XIX)
KC 250 III Gr	-	{ 3 green rings) Tabun. (Fig.XXII)
KC 50 II Bu	-	{ 2 blue rings) DM generator. (Fig.XXIII)
KC 250 W	-	{ 2 white rings) CAP. (Fig.XVIII.)

Two types which have not been accepted into the service may be found in small quantities.

KC 500 II Gr - (2 green rings) phosgene
KC 500 W - (2 white rings) CAP.

25. Charging of chemical munitions

Information on the machines used for charging various chemical munitions was obtained by an examination of machines found at the Nebelfüllstelle, Munster Nord, and at the Luftwaffe Munitions Anstalt, Oerrel, as well as by the questioning of technical personnel. A description of these machines and their method of use is given in the following paragraphs, but further details may be expected in separate reports to be issued later when the investigation at the works of the makers of the charging machines, and running tests at the Nebelfüllstelle, have been completed.

Charging bombs with phosgene. This was done at the Nebel-füllstelle, Munster Nord by passing phosgene through cooling pipes, fitted overhead in the filling room to a vertical feed pipe approximately 6 feet long, at the bottom of which was fitted a hand valve. To this valve was fitted a small bore pipe sloping slowly down towards the bomb. At the end of this pipe was fitted another hand valve, attached to the outlet of this valve was a flexible pipe for insertion into the bomb which was stood on a small weighing platform. The valves were opened and phosgene allowed to enter the bomb until the required weight registered on the scales. It was stated that a charging machine was not warranted owing to the small number of bombs filled at this station.

Semi Automatic charging machines manufactured by Hagemuk of Kiel had been received but not installed. A contract was given to this Firm to design and develop a charging machine to fill and seal shell under pressure. In view of the urgent requirement permission was given for 6 machines to be built as soon as the design was considered to be promising. Delivery of 2 machines was made and trials were carried out which eventually proved that

the machines were unsatisfactory to fill the original requirement, which was to charge and seal shell with phosgene at normal temperatures.



Semi Automatic Charging and Sealing Machine for
Charging Phosgene at Normal Temperature.

Manufactured by Hagemuk of Kiel.

Filling Head is in Position over Shell Vice.

The machine comprised the following components :-

- (i) A measuring cylinder fitted with sight glasses and electric light.
- (ii) A float which operates an outlet valve to the charging nozzle.
- (iii) A combined charging and sealing head which can be rotated through 180 degrees.
- (iv) An oblong table fitted with a shell vice at each end which moves through 360 degrees, locked at 180 degrees intervals.
- (v) A foot pedal which releases the locking catch for the table.

The operations for charging and sealing were as follows :-

- (i) Place shell to be charged on vice and clamp in position.
- (ii) Rotate table 180 degrees to bring shell under charging head.
- (iii) Place screwed sealing plug in spanner in charging head and rotate head 180 degrees to the right. (This operation was stated to be frequently forgotten).
- (iv) Lower charging nozzle into the shell by moving right hand lever to the rear, when liquid will fall by gravity into the shell. Observe measuring cylinder and when empty pull right hand lever forward, where it is locked, this lifts charging nozzle out of shell.
- (v) Rotate charging head 180 degrees, pull left hand lever forward thus bringing spanner in contact with filling hole and using the hand wheel provided, enter and screw the sealing plug downwards when the plug is tight, final screwing is done by means of the hand ratches attached to the sealing head until the head of the screw is broken off.
- (vi) Return left hand lever to its original position thus lifting the sealing spanner up from the shell, place screwed sealing plug in spanner, and rotate the charging head back to its original position, bringing the charging nozzle into position for charging.
- (vii) Release the table catch by depressing the foot pedal and rotate table through 180 degrees, thus bringing an empty shell to the charging head and remove the filled shell from the opposite end of the table.

Gebrüder Schaffler of Berlin had a similar contract to that given to Hagenuk of Kiel and produced a machine very similar in design but equally useless.



Semi Automatic Charging and Sealing Machine for
Charging Phosgene at Normal Temperature.
Manufactured by Gebruder Schaffler, Berlin.

Charging shell with vesicant. Semi Automatic rotary charging machines manufactured by Gebrüder Schaffler of Berlin had been installed and tried out charging 10.5 and 15 cm. shell with unthickened chargings.

The charging head was fixed and fitted with concentric nozzles for constant gauge depth filling, a semi rotary hand operated liquid supply and vacuum disc valve, a separator and return pipe and vacuum gauge.

The sealing head was fixed and comprised a continuously rotating motor fitted with a spanner which had a lead-in for the square on the screwed sealing plug.

The rotating table was fitted with 6 vices and the speed of rotation was automatic once it has been fixed according to the size of the weapon to be charged. The table was rotated by an electric motor through an infinitely variable cone drive.

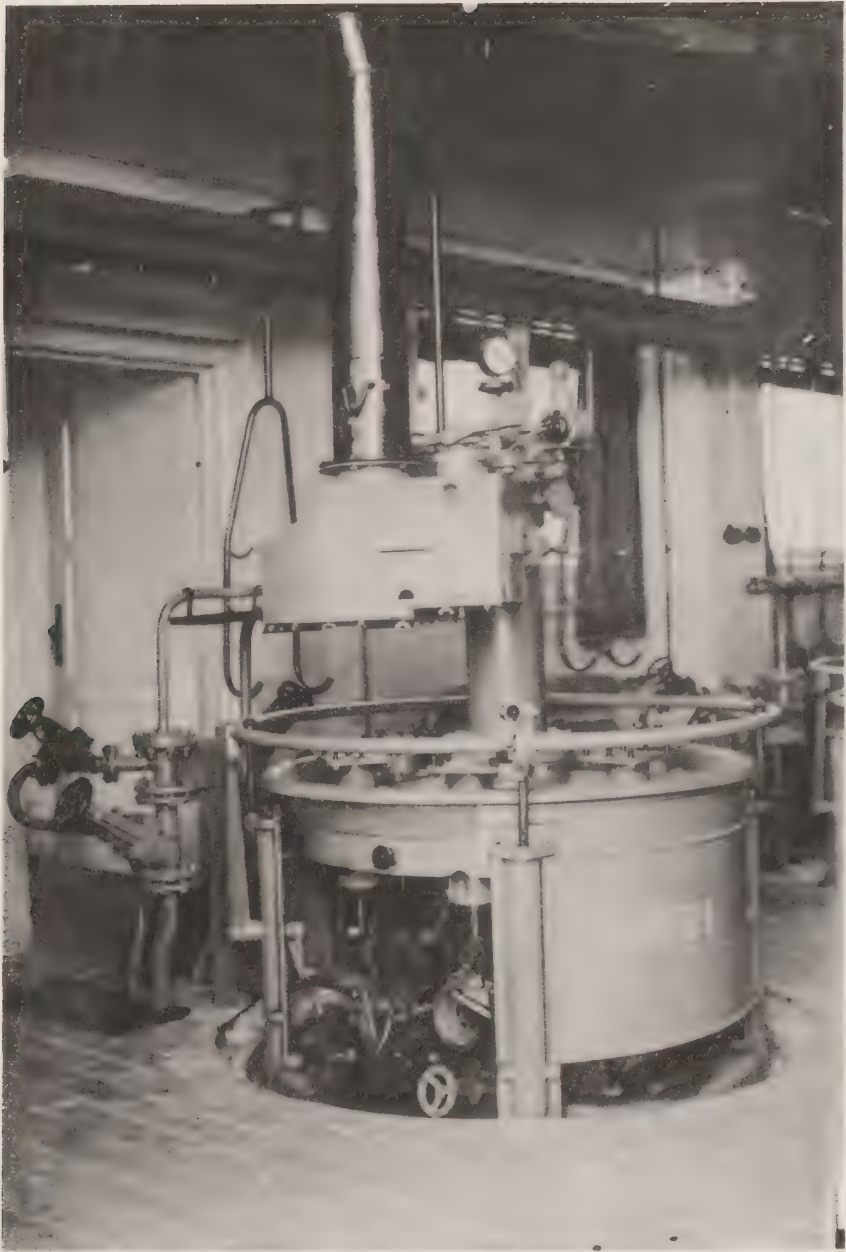
The shell were lifted to the charging and sealing heads by means of two cams which pick up the vertical shaft of the vice table which was fitted with a roller.

One operator stood between the charging and sealing heads and inserted a screwed sealing plug as the charged shell comes round.

The charging operator started the machine and the shell was lifted up to the charging nozzle. The rotary valve lever was moved from the right to the left until locked in position. The vacuum seal was made on a shaped rubber pad and liquid induced into the shell. The charging operator observed the separator through the sight glass and immediately liquid was seen the rotary valve lever was lifted to release the locking plunger and returned to the right automatically by a spring. This opened the breaker leak port and the shell was lowered by the cam and the table rotated 1/6 of a turn. A screwed sealing plug was now inserted and after further movement of the table the shell came under the sealing head. The shell was lifted by the cam and the rotating spanner picked up the square head of the sealing plug which was screwed home until the squared head was broken off. The shell was now lowered and the table rotated once more. The sealed shell was removed and conveyed away.

This machine could be started up only by the charging operator but in case of accident or any other reason it could be stopped by anyone around the machine.

The charging operator lifted a small catch immediately in front of the charging head, and by means of a hand rail which ran round



Semi Automatic Rotary Charging and Sealing Machines.
Manufactured by Gebruder Schaffler, Berlin.

Note :- Operating Electric Motor Under Table has been
Removed.

the table, he moved the table about 3 inches to the right. This moved a lever about 90° away from him which started the machine. By reversing the movement of the hand rail the small catch engaged into its slot and the starting lever returned to the off position.

Semi Automatic charging machines manufactured by Gebruder Schaffler of Berlin had been installed and tried out, charging 10.5 - 15 cm shell and 8 cm Mortar bombs. These machines are of the single table type.

The charging head was fixed and was fitted with concentric nozzles for constant gauge depth filling, a semi-rotary hand operated liquid supply and vacuum disc valve, a separator and return pipe, a vacuum gauge and thermometer for use when thickened chargings were used. Sealing of the shell or mortar was done by hand.

The table was fitted with a vice, which slid on two runners and was located by a stop on the table. The shell was lifted to the charging nozzle by means of a heavy counterweight fitted at the rear of the machine.

These machines were intended for installing in batches, and were fitted to a common vacuum line.

The sequence of operations were as follows :-

- (i) Depress foot lever in front of machine to lower table which is locked in down position by a spring loader lever on the left hand side of the machine.
- (ii) Load shell on to vice, ensure shell is in correct alignment and push vice against stop on table.
- (iii) Ensure that liquid supply valve lever is towards right of machine.
- (iv) Release spring loaded lever on left of machine when table will be raised to charging head by means of the balance weight.
- (v) Move charging valve lever to left until it is locked in position. Vacuum should now be on and shell filled. Operator watches for liquid in separator by observing through the sight glass and when liquid is seen the liquid supply valve lever is lifted and moved to the right, this opens a small breaker lead and vacuum is destroyed.



Semi Automatic Charging Machine for Thickened or
Unthickened Mustard.
Manufactured by Gebruder Schaffler, Berlin.

Note :- Thermometer in Charging Line.

- (vi) Depress foot lever in front of machine to lower table until it is locked in down position. Insert screwed sealing plug and tighten fully by hand until top of plug is broken off. Remove shell and replace by another empty.

The charging rate of this machine was 100-120 per hour for 10.5 cm. shell. Two of these machines had been converted into rotary charging machines for filling rocket heads.

Fully automatic charging machines manufactured by Hagemuk of Kiel had been installed and tried out, charging 10.5 - 15 cm. shell with unthickened liquids.

Each machine was mounted complete with vacuum and hydraulic pump onto a metal base plate and could be transported almost complete for installation.

The charging head was of the sliding type, being moved downward by hydraulic power and spring returned. The charging nozzles were in the form of concentric tubes for constant gauge depth filling. The inner tube was for liquid and the outer tube for vacuum. The sealing head comprised a continuously rotating motor fitted with a spanner to take the squared end of the screwed sealing plug. This head was lowered hydraulically and returned by springs.

The table of the machine was of the rotary type, fitted with 8 shell vices and rotated by electric power through a worm wheel and worm continuously running.

Intermittent movement of the table was obtained by the action of a sliding arm horizontally mounted and hydraulically operated which pushed forward a spring return cam which engaged with a projection on the main worm wheel shaft, rotating the table $1/8$ of a turn. An hydraulic interlock was provided under the table which located and locked the table in the correct position under the operating heads.

Three men were required to operate this machine; one to load empty shell, one to insert the screw plug, one to remove charged and sealed shell.

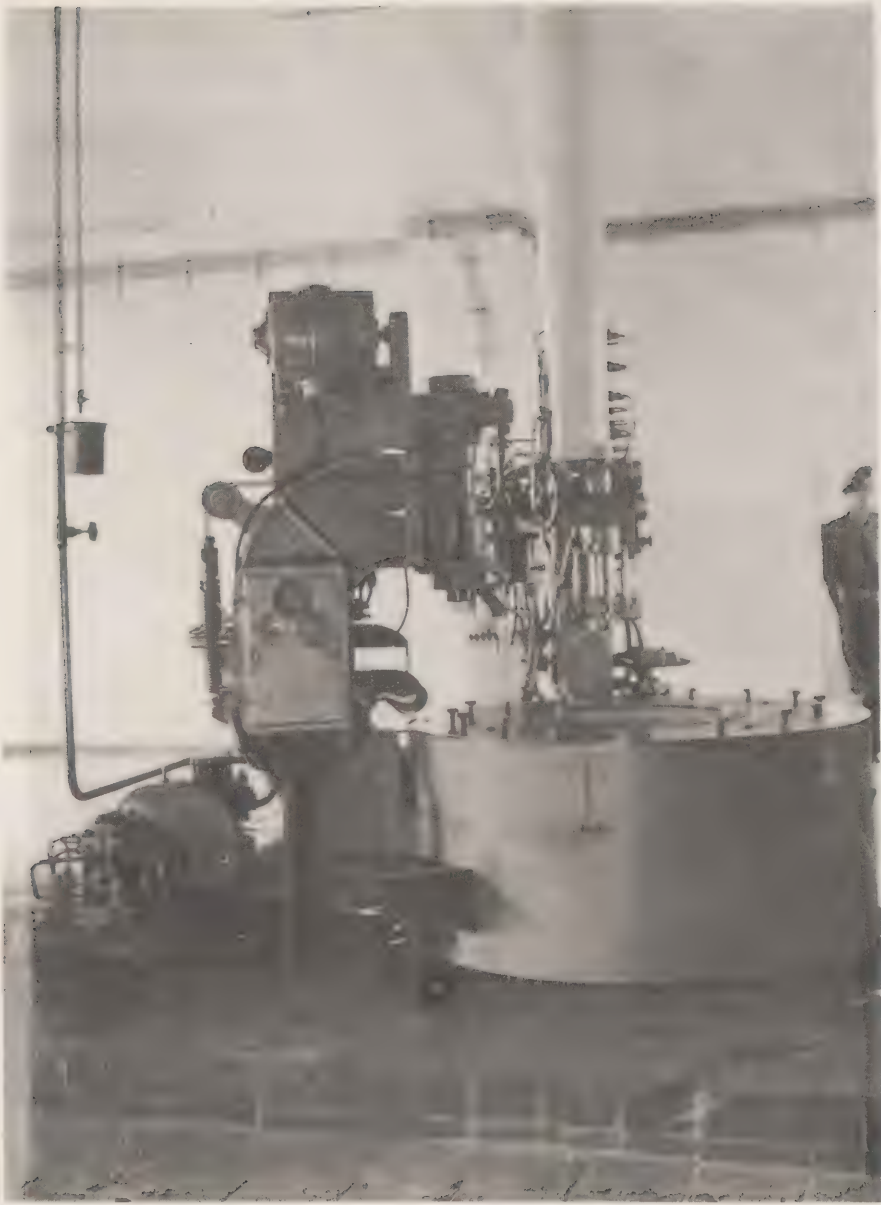
Empty shell were picked up by special lifting tongs fitted with locating arms which were fitted with small projections and which register in the charging hole of the shell, and into two holes on the shell vice, thereby ensuring the shell was the correct way up and in correct alignment to receive the charging nozzle. When the



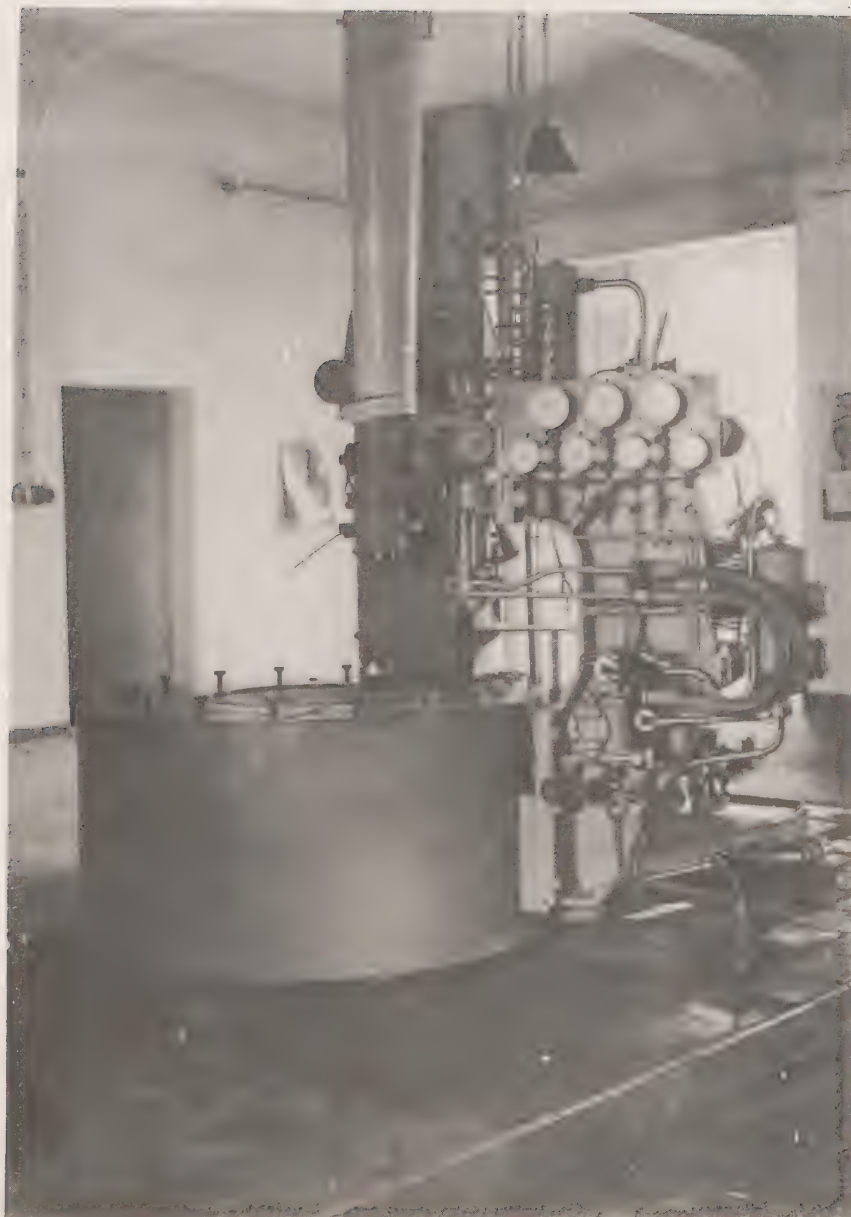
Semi Automatic Charging Machine for Thickened or
Unthickened Mustard.
Manufactured by Gebruder Schaffler, Berlin.

Converted into Rotary Charging for use in
Filling 15 cm. Rocket Heads.

Note :- Charging Heads are Missing.



Fully Automatic Rotary Charging and Sealing
Machine for Filling Unthickened Mustard.
Manufactured by Hagemik of Kiel.
View Shewing Sealing Head and Spring Return



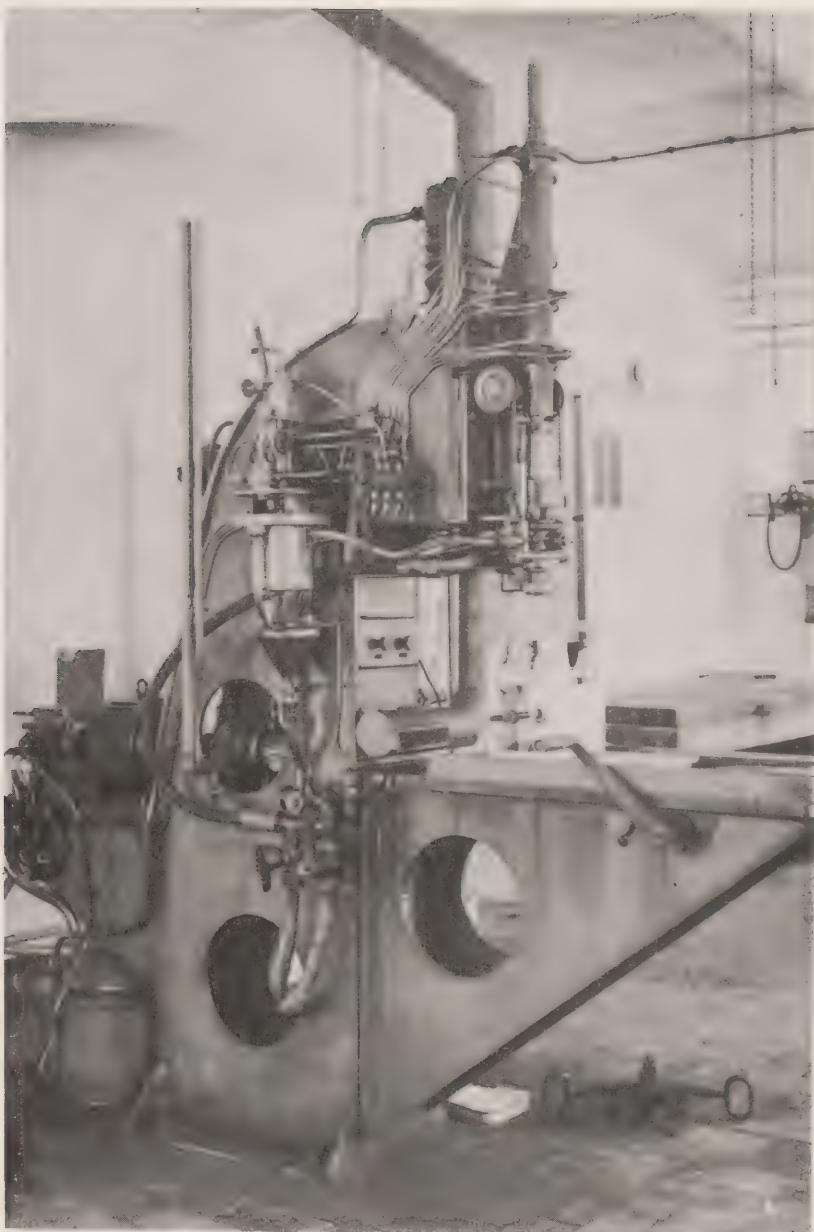
Fully Automatic Rotary Charging and Sealing
Machine for Filling Unthickened Mustard.
Manufactured by Hagemuk of Kiel.
View Showing Charging Head and Control Panel.

shell had been clamped in the vice the lifting tongs were removed. The charging operator started the machine, the table rotated $1/8$ turn to bring the first shell under the charging head, the head was lowered, a vacuum seal made by the pressure of the head on a shaped rubber pad around the charging nozzle, the shell evacuated and the charging induced into the shell until it reached the level of the nozzles, surplus liquid drawn through the vacuum tube into an overflow separator and thence to a reservoir underground. The vacuum was now broken by the operation of a breaker leak, and the charging head raised by means of the return springs, the table rotating $1/8$ turn. The operator sitting between the charging and sealing head then inserted a screwed plug into the charging hole of the shell which was ready for sealing on the further movement of the table which brought the shell under the sealing head. The sealing head was lowered by hydraulic power and the rotating spanner, which has a square recess, fitted with a lead, picked up the squared head of the sealing plug and screwed it into the shell. When the sealing plug had been screwed firmly home, the top of the plug was twisted off by the rotating spanner and the shell sealed. The sealing head was raised by the return springs and the table moved around $1/8$ turn when the unloading operator fixed the lifting tongs onto the shell and it was removed. Although this machine was originally designed to be fully automatic, it was observed that one operator inserted the sealing plug by hand and the reason given for this was that the automatic magazine for screw plugs gave so much trouble by jamming or cross threaded entry of plugs, that it was discarded in favour of hand insertion.

The rate of charging by this machine is approximately 240 per hour for 10.5 cm. shell or 120 per hour for 15 cm. shell.

This machine could not be used for Thickened chargings.

Fully automatic machines for single shell filling manufactured by the same firm had been installed. The charging operation is exactly similar to that described above. The shell was lifted onto the table by the lifting tongs, and located in the correct alignment in the vice. The vice is moved under the charging head and located against a stop and the charging head lowered. When the shell had been filled, the charging head was raised and the shell moved forward, a screwed sealing plug inserted and tightened by hand until the top was broken off. The shell was then removed and another empty shell placed in position.



Fully Automatic Charging Machine with Hand Sealing.
Manufactured by Hagenuk of Kiel.

Note :- Shell Lifting Tongs on Floor.

Charging of No.42 Rifle Grenade A small semi-automatic charging machine for filling these rifle grenades with AC was examined. The essential features were an oblong table with a rotating fixture to take 10 grenades for filling, a charging head and a sealing head. One operator sat or stood on front of the charging head and loaded the empty grenade on to the rotating fixture from a stock of empties close to the machine and on his right side. The fixture rotated clockwise and another operator on the opposite side of the table and to the left of the charging operator, removed the filled grenade from the rotating fixture, and after inserting the liquid sealing cap and detonator tube into the grenade he placed the grenade in a vice under the sealing head, which consisted of a continuously rotating motor driven spanner fitted with a slipping clutch. This head was lowered by hand and when the sealing cap was fully tightened the clutch slipped and the head was raised. The seal was made on a lead washer fitted into the underside of the sealing cap. This operator removed the filled and sealed grenade and placed it into a box on his right side, which when full was taken away. The liquid was drawn by vacuum into a cylinder, mounted on top of the charging head column, which was fitted with a coil of tubing, through which the AC was drawn into the grenade; cold water being continuously circulated around this coil to maintain the AC at a temperature of about 6°C. A charging rate of 400-600 per hour per machine was claimed, but in practice 400/hour is considered the most economical speed as above this figure the sealing head operator became a bottleneck.

Charging of aircraft bomb with vesicant. Semi automatic charging machines manufactured by Gebruder Schaffler of Berlin had been installed for filling 250 and 500 Kg. bombs with mustard at the Luftwaffe filling station at Oerrel.

This charging head was of conventional design and works on the constant gauge depth principle as used by this Firm on all their machines. The bomb to be filled was placed on a special trolley which was fitted with a jig to locate the bomb in the correct place for the charging nozzle, the trolley was also located by a jig on to a platform immediately under the charging head by means of the platform, a vacuum seal is made by means of the rubber pad around the charging nozzle and liquid was drawn from the underground storage tanks immediately below the charging machine; when liquid reached the level of the charging nozzle, the surplus was returned to the underground tank via the vacuum nozzle and a separator. The platform was lowered, a screwed sealing plug was fitted and fully tightened by hand until the top had broken off, and then the trolley was released from the platform and rolled away. It was stated that bombs could be filled with liquid without being removed from their transport



Semi Automatic Charging Machine for Filling and
Sealing No.42 Rifle Grenades with AC.
View Shewing Measuring Cylinder in Position
and Sealing Head on Right of Machine.

base. The temperature of the charging room was maintained at 20°C. The time taken to charge a 500 Kg. bomb was approximately 2 minutes.

Mobile charging machine. A mobile charging plant was seen at Oerrel, but it had been completely wrecked. By interrogation it was learned that this machine, mounted on a special railway truck had been intended as a reserve filling plant in case of breakdown of the fixed plant. It was further stated that mustard was the only charging used with this plant. Similar mobile charging plants were stated to be at St.Georgen and Locknitz.

Hand operated machine for charging ampoules for 20 and 30 mm. shell. A brief description of a small hand operated charging machine using thickened mustard for the above ampoules was obtained by interrogation. No sample of this machine was available, it having been sent to Raubkammer from Spandau, was later sent to the Air Force filling station at Oerrel, but was further despatched from there to an unknown destination.

This is apparently a simple piston or plunger type of machine which by manipulation of the handle induced a charge of thickened mustard into the ampoule in the form of a ribbon of paste similar in consistency to thick porridge. This machine had been used very little and a complete description could not be given. After the ampoule was filled it was removed from the charging machine and a push on cap was fitted over the top of the ampoule. A klingerite washer was fitted into this cap and the top of the ampoule was turned inwards at an angle of about 45° to form a seal on the washer. The skirt of the cap was then rolled into a cannalure already formed on the body to form a liquid tight seal. Approximately 1 per cent leakers was experienced.

When asked why this machine had been sent to an Air Force filling station, it was stated that the 20/30 mm. shell charged thickened mustard has been accepted as an Air Force Store, but no confirmation of this was obtained from any other source.

Charging munitions with CN. No charging machines have been seen for use with CN, it being stated that this was done by hand, the CN being heated to 60°C and poured into the munition through a funnel. Sealing of the munition also was done by hand.

Charging experimental munitions with Aeroform. This was done by weighing the required amount of Aeroform into a container, which was placed in position on a stand about 8 feet above the weapon. Immediately below the outlet to this container was fixed a funnel and trunking leading down to the munition. In the case of the 250 Kg. bomb, a special large filling hole was made in the nose, into which a portable funnel was placed, the bomb was stood on to

a shaking machine and the contents of the top container was fed by gravity into the bomb, piling up of the charging being prevented by the agitation caused by the shaking machine. When the supply container was empty the bomb was removed from the shaking machine and sealed by hand.

26. Smoke Munitions

The information obtained on smoke, which was entirely confined to Army smoke munitions, can be classified under three headings (A) coloured smoke, (B) Army smoke munitions such as shell and small generators, (C) area screening munitions. These are taken in order below :-

(A) Coloured smoke was not developed by Prüf 9 but by Prüf 1, which in February 1945 had absorbed Prüf 7 the department formerly dealing with signal devices. Very little information was therefore obtainable on this subject. It was learned however that the possibility of using coloured smoke for camouflage by imitating the landscape was being investigated, and that large generators for this purpose were being made by Pommersh Ind. Barth.

(B) Shell and small generators. Very little, if any development of smoke mixtures was carried out at Raubkammer or Spandau, the work mainly being carried out at factories. The factories concerned have been investigated as separate targets. The following information was however obtained :-

A black smoke having a composition of

60 per cent Anthracene
38-39 per cent KClO_3
1-2 per cent Kieselguhr

had been filled into generators, and opinion was beginning to favour the use of such generators for night screening in place of the white smoke produced by chlorosulphonic acid mixture. A grenade made of glass was evolved for the attack of tanks. These were originally charged TiCl_4 but later SiCl_4 was added to reduce the freezing point and so counter the low temperatures prevailing in Russia. The incorporation of CaCl_2 in these mixtures to increase the rate of moisture adsorption was mentioned. The water contained in an inner tube was stated to be for the purpose of accelerating the formation of solid decomposition products in order to obscure the periscopes of tanks. A new flat type for fitting conveniently in the pocket was under development.

Questioned as to the reason for adopting SO_3 as the standard charging for smoke shell and rockets, it was stated

that it was realised that WP was the better smoke producing agent, but there was none available for this purpose and SO_3 was adopted as the next best. They had now experimented with a base-ejection smoke shell, having seen and tried the British B.E. smoke shell. The trials had, however, been confined to the 7.5 cm. I. Gr (Infantry gun) shell using a single ejected canister with an HE ejection charge. The method of use was to fire at short range and steep angle of descent, and complete or partial burying of the container often occurred with the consequence that the performance was no better than that of the SO_3 shell. No trials were done with multiple containers.

No smoke trials of smoke shell in deep snow had been carried out. It has been found that a rocket with a rear bomb gave good results on water and marshes. SO_3 shell lost 75 per cent of their efficiency in very cold weather.

(C) Area screening munitions.

Smoke material. Experiments were carried out in 1932 using $\text{SiCl}_4 + \text{NH}_3$ as a smoke agent, due to the very poor quality of CSA being produced at that time. The resulting smoke from this mixture was extremely good at all temperatures, but on account of the bulkiness and difficulty of construction of the apparatus, this method of producing smoke was not adopted. One witness stated that he considered this the most effective of all smokes.

Up to early 1940 the standard filling for spray generators was 60 per cent SO_3 + 40 per cent CSA, but during the very cold weather of this period, trouble was experienced with this mixture and it was decided that 50/50 and 40/60 mixtures should be tried. The 40/60 mixture was found to be unsuitable and the 50/50 mixture was adopted as the standard. Even these mixtures were not satisfactory as the smoke produced was found to be of poor quality at temperatures below 5°C . During hot summer months 60/40 is sometimes used.

Experiments had also been carried out using TiCl_4 as the smoke agent and very good smoke was produced in any temperature down to about -20°C . This smoke agent was used on the Russian front whenever the TiCl_4 was available. It was stated that the solid deposit around the spray could be easily removed and did not interfere with the quality of the smoke produced.

The Germans had no knowledge of oil smokes and displayed great curiosity about the Esso Generator. Their knowledge of this was based solely on journalistic accounts and they were mystified about the role played by the water in the process of smoke generation.

Apparatus. The standard smoke apparatus is known as NEBEL ZERSTAUBER 33. It is filled with 25 litres of smoke liquid, the air being admitted to the top of the liquid at a pressure of up to 8 - 10 atmospheres. Spray jets passing $\frac{1}{2}$, $\frac{3}{4}$ and 1 litre per minute could be used with this apparatus, but the normal spray used was $\frac{1}{2}$ litre/min. which would give smoke for a period of 45 - 50 minutes.

Filling with acid mixture from storage drums. A storage drum was rolled into position with filling bung uppermost. The bung was removed and the filling gear attached. This consisted of a dip pipe, hand valve, inlet pipe for air and outlet pipes for acid.

A portable air compressor or hand pump was connected to the air inlet pipe, and air was admitted to the storage drum until 1 - 2 atmospheres was showing on the pressure gauge. Three smoke containers were placed upsidedown on to a special stand and the filling hole plugs removed. The free end of the liquid supply pipes was then inserted into each drum, the acid valve on the filling gear opened, and liquid transferred to the smoke container until 25 litres was shown by dip stick to have been transferred. The filling hole plugs were now screwed down tightly to form a liquid tight seal.

Charging with air. With the smoke container still on its stand, the extension to the dip pipe complete with valve, was fitted to each container. A portable air compressor was connected to each of these extension pipes in turn, the valve opened and air admitted to the container until 8 - 10 atmospheres was showing on the pressure gauge. The valve was closed, the air charging line removed, and the containers taken out of the stand and placed upright on the ground.

Method of filling by machine. The charging machine for filling this apparatus with CSAM consisted of

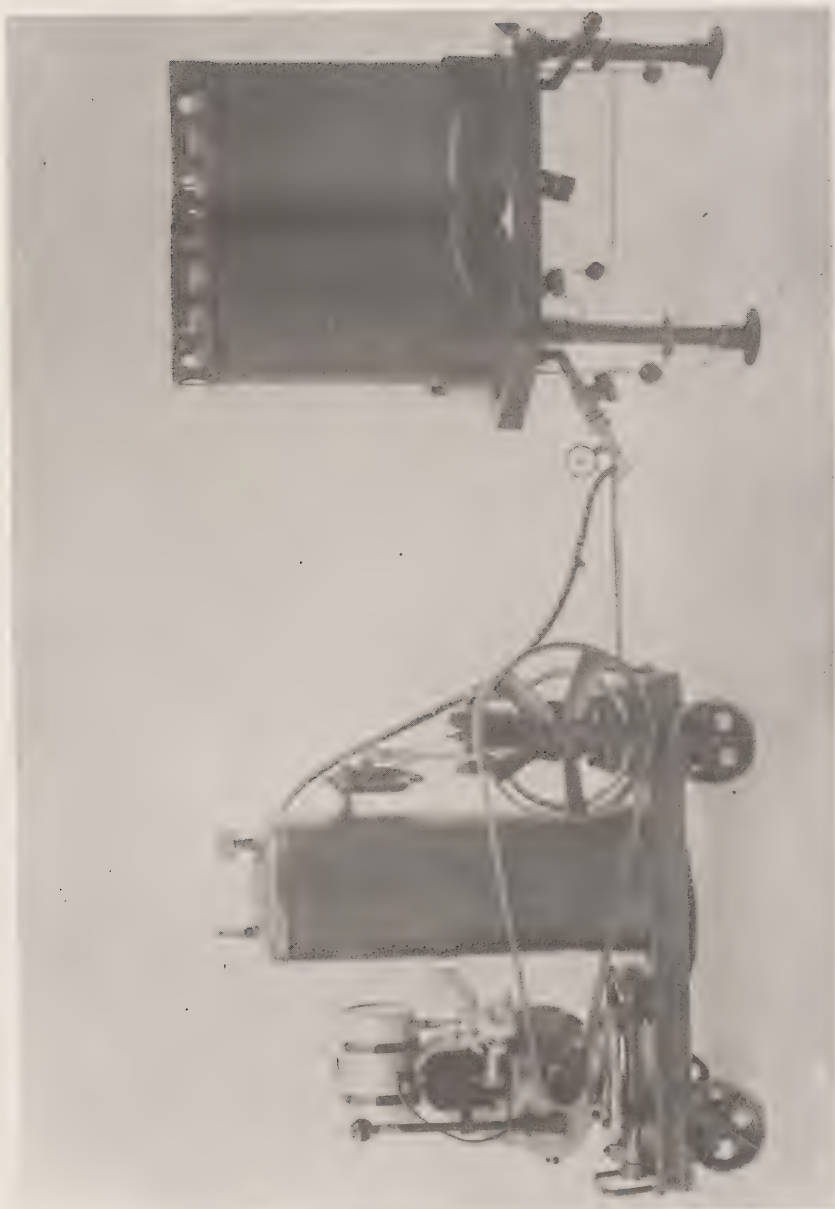
- (i) Storage container for bulk CSA, Tank wagon or standard storage drum.
- (ii) Machine fitted with measuring cylinder, hand controlled outlet valve, sliding head, and charging nozzle.
- (iii) Air reservoir with pipes, valves and flexible charging line.



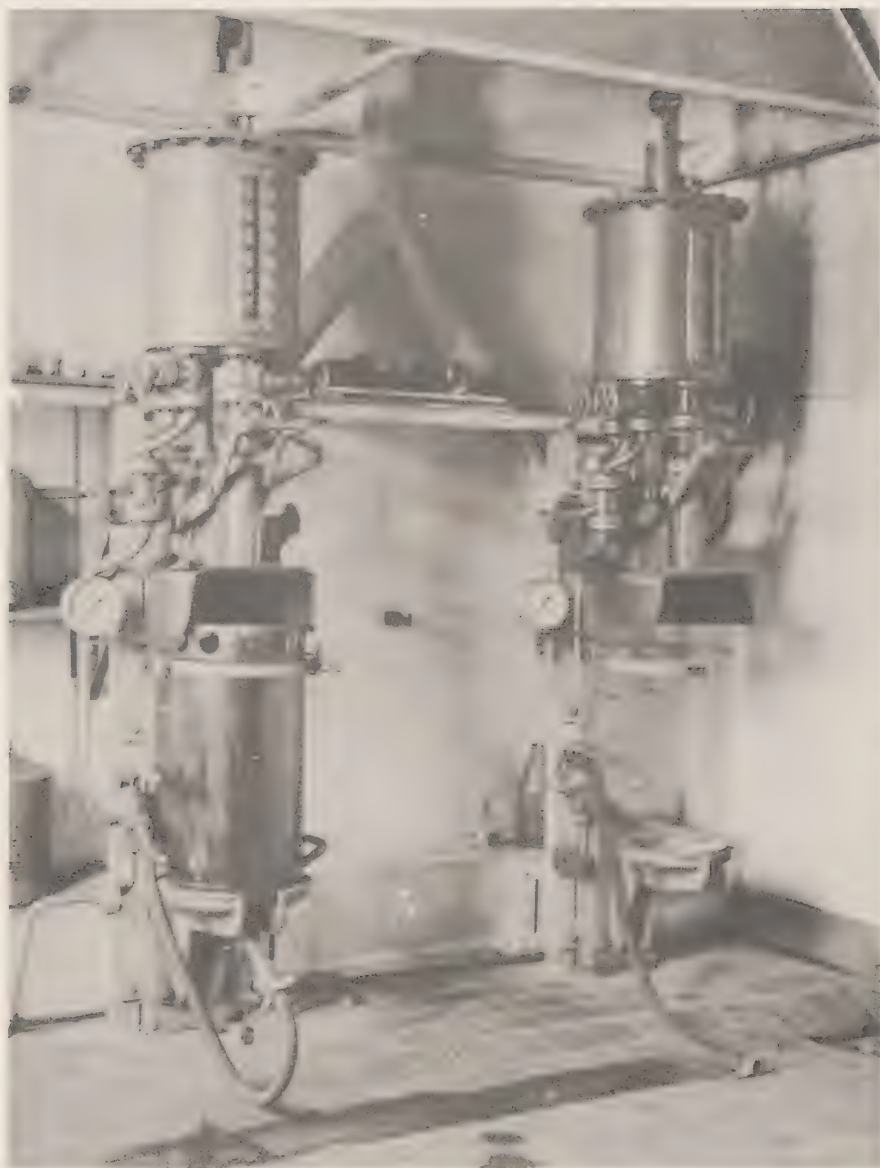
Nebel Zerstauber 33.



Filling with Acid from Storage Drum.



Charging with Air from Portable Compressor



Machine for Filling Nb Zst. 33 with CSAM
and Compressed Air.

Procedure. The smoke container was prepared as for hand charging and was placed in air inverted position into a special housing fitted with quick release clamps. The measuring cylinder was filled with 25 litres of liquid from the bulk supply. The charging head was lowered until the nozzle had been fully inserted into the container. The hand controlled outlet valve was opened and liquid flowed by gravity into the container until the measuring cylinder was empty. The valve was now closed and the charging head returned to its original position. The charging hole plug was fully tightened to form a liquid tight seal. The compressed air line was now connected to the extension pipe previously fitted and an air lever on the machine was depressed admitting air into the container until 8 - 10 atmospheres showed on the gauge. The air lever was returned to its original position, the extension pipe valve closed and the compressed air line disconnected. The smoke container was now removed from the charging machine and placed in an upright position on the ground ready for fitting the spraying components.

Fitting up for spraying. A further extension pipe, fitted with a cylindrical filter made of mono-metal was then connected to the outlet valve on the container, a conical disc screwed on to this pipe and the spray jet fitted to the end of the pipe. Single or twin pipes could be fitted to this apparatus.

Spray Jet. This comprised 4 components. (1) Body, (2) Insert with slightly tangential holes, (3) Metering disc, (4) Screwed cap. (1), (2) and (4) were made from V2A steel, and (3) from messing, a Copper Zinc bronze.

The use of the circular disc immediately behind the spray nozzle was mainly to protect the operator.

All spray jets were calibrated with water, not CSAM. No special drying precautions were taken after smoke containers had been washed out. They were allowed to drain empty. No system of CSAM remote control was used by the Army. All large static installations for screening ports, factories etc. being controlled by the Luftwaffe.

Care and Maintenance. Ordinary thin lubricating oil was used on screw threads. Asbestos graphite string was used for packing valves. Ordinary grease was used for transit purposes. All pipes were made of steel. All screwed components were made from bronze or V2A. The spray was not removed after making smoke, and no attempt was made to seal the acid pipe from ingress of moisture

from the atmosphere. Lead was used for jointing washers.

Very little corrosion trouble had been experienced.

Precautions when filling with acid. Operators wore leather jacket and trousers, rubber or leather gloves, eyeshields or respirator without filter.

First Aid Treatment

Eyes Liberal washing with 1 per cent bicarbonate solution followed with boric cream.

Exposed skin Liberal washing with water.

Miscellaneous Containers. A new design of transport drum for CSAM had been introduced and a very limited number made. This drum could be fitted up as a spray unit, the components for this being contained in clips attached to a loose lid which was held in place by 4 screws. The total capacity of this drum was 120 litres, but the volume of acid charged into the drum was approximately 90 litres. Air was admitted directly on top of the liquid to 8 - 10 atmospheres. Spray jets of 1 or 2 litre per minute were used when fitted up for spraying. It was intended that all future production of transport drums for CSAM should be made to this design.

27. Description of Sections at Raubkammer dealing with Chemical Munitions

(A) Bereich RVI

The complete layout of RVI is shown in Fig. XXV. The dimensions of the enclosure are approximately 600 m. x 400 m.

The buildings are arranged with due regard to explosion risks, and bunkers house the large stocks of HE and charged munitions. Well surfaced roads give easy access to all parts and entry from the main public road is through standard wired gates. The recent arrival of material from the Spandau Departments IVaL, F and 6B had taken place this being deposited in the administration building, Haus P and Haus F, etc.

The following is a description of the various buildings and their contents.



Transport drum with spray fittings

The entrance gates are flanked by the guard house, where all the keys were held, and the administrative building. The administrative building held papers and files recently evacuated from Spandau. Adjoining the guard house are washing and drying facilities, and here are stored decontamination equipment and canteen facilities.

The stores or quartermasters receipt and despatch buildings are about 50 m. from the gates. In these was a store of igniters, boxes, empty munitions etc. There were also small workshops.

Haus A contains machinery and apparatus for melting CW agents and nitro cellulose; for mixing; and for extruding nitrocellulose into bands 7 x 2 mm. in size, this machine was capable of producing 40 bands simultaneously. Attached to the building was a laboratory for routine analytical work.

The bands of CW agents and Nitrocellulose were passed by an enclosed conveyor to Haus B. In this there was machinery for cutting up the extruded bands. A drying room for the small pieces was provided, this building having its own motive power for driving all the machinery.

Haus C contained pressing plant and a drying room for smoke mixtures. A shaking machine was available for consolidating mixtures in containers.

Haus D contained laboratory equipment evacuated from Spandau VIB. The recent arrivals appeared to have settled in and commenced work. The main bulk of the apparatus was electrical and photographic.

Haus E was the room in which shell etc. were weighed, painted and assembled ready for headfilling. It was empty except for some British 25 pr. B.E. smoke shell. Examination of foreign munitions took place here.

Haus F building contained a laboratory, a small semi-scale plant and a charging machine. Attached were baths for washing, and the usual decontaminating materials, and clothing. Among the materials charged were AC, CK and CG. Oxygen sets were present in the charging room. A small stock of detonators and bursters was held. A large cellar with tiled walls contained drums of various CW agents. A small room capable of housing the standard 200 gallon drums fitted with pipes appeared to have been used to warm thickened mustard in order to decrease the viscosity prior to charging.

Haus P was stated to have been taken over as the office of Vial Spandau. Attached was an experimental pressing room suitably protected, for use with mixtures containing HE. Fume cupboards held some pre-pressed pellets containing CN and PETN and the standard cardboard shell liners were available for filling. A few of these containers were already filled with pellets and a stock of shell fuzes was held.

Haus W was an underground tropical or high temperature storage chamber. It was fitted with individual cabinets which could be electrically controlled at the required temperature. When examined no stores were present.

The six bunkers (Munition Haus 1 - 6) situated on the perimeter of the area remote from the main road are of massive construction, concrete and earth, and are entirely above ground. Natural ventilation through openings in the roof is provided.

M.H.1 contained black powder and propellant charges for the 30 cm. Wurfkorper.

M.H.2 contained 30 cm. Wurfkorper charged O-lost, 150 mm. smoke shell, and 8 cm. W.Gr. smoke.

M.H.3. held Sp.Bu 37 mines charged with experimental fillings, 75 mm. shell with cast CAP/HE (?) fillings. Also there was a stock of BE containers for shell, filled DM mixture which had come from I.G.F.Hüls.

M.H.4 held various headfilling HE pellets for smoke ammunition, and a stock of propellant charges.

M.H.5 held empty hand grenades which had an embossed hexagon on the base, also a number of empty smoke and toxic smoke containers which were identified as components of cluster bombs.

M.H.6 held egg shaped hand grenades 42, black smoke generators, green and brown smoke generators, floats for Nb K.39, and experimentally filled smoke generators both static and for projectors.

Haus N contained a CSAM filling plant, drums filled with $TiCl_4$, $ZnCl_2$ etc., transport drums and spare and repair kits for smoke spray installations. It also housed hydraulic presses for dealing with the insertion of toxic smokes into generators or containers. The presses were well screened and operated by remote control. An assembly room held black powder and a number standard pull igniters.

There were a number of miscellaneous storehouses as follows :-

L.H.1 - 4,200 Kg. of D.C. ex Lonal Haselhorst made in Nov. 1943 and a stock of glass grenades filled $TiCl_4$.

L.H.2 - Army Gas Laboratory equipment, dummy 250 Kg bombs experimental chargings and a mixed collection of smoke equipment, chiefly empty.

L.H.3 - Store of empty boxes.

L.H.4 - Store of empty boxes, and material from VIAL Spandau. It also holds a stock (about 5000 kg.) of Aeroform, CAP, chlorbuna of varying viscosities and a stock of thickeners.

L.H.6 held a small amount of material from Spandau VIbL. It showed evidence of having been used for headfilling and fuzing rockets and shell.



Entrance to RVI.



RVI - Stores Receipt and Despatch Building.



RVT - Haus A, B, C and D.



RVI - Haus E.



RVI - Haus F with Haus K in Background.



XVI - Haus P.



RVI - Haus W.



RVI - A Typical Bunker.

Haus R contains low temperature climatic storage chambers and refrigeration plant. Experimental phosgene charging could have been effected here.

Miscellaneous buildings included Fire station, Water tanks and supply, Salvage dump, Oil store, two air raid shelters, Corrugated iron huts, A general store of empty shell, bombs rockets and components, therefore in large numbers.

(B) Erprobungstelle der Luftwaffe

The Erprobungstelle der Luftwaffe is located in an area between the RVI and RIX areas of Raubkammer bei Munster. It is comprised of five small buildings of temporary type construction, a medium size 2 story brick building and several bunkers. The 4 small buildings near the entrance contained the guard and details of administration, general stores and a small museum of Air Force CW munitions. The brick building housed a well equipped chemical laboratory, a balance room store rooms, a heating plant and a room that was equipped with ventilators which could be used for bomb filling purposes. Adjacent to this there was a long building equipped for fuzing bombs.

The bunkers contained various sizes of bombs, varying in size up to 1800 Kg. including experimental types. Bombs were also stored in well camouflaged open areas. A large percentage of the bombs were unfilled. Supplies of chemicals, especially chloroacetophone, were also found.

The area was obviously used for trial fillings of bombs with CW material, especially gases.

The Museum was a temporary one story building about 20 ft. x 30 ft. containing the following :-

- Sectioned German bombs.
- British 250 and 30 lb. bombs.
- An American M47 A1 bomb.
- French, Russian and Italian bombs.

Russian spray tanks marked UdSSR WAP-6, UdSSR UCHAB-500 UdSSR WAP-500, UdSSR WAP-1000 labelled for "Kampstoffe u. Brandfluessigkeit" (CW gases and incendiary liquids). Also UdSSR UCHAB -250 and UdSSR UCHAB-500, which were labelled for Kampstoffe u. Nobelsaure (CW gases and chlorsulphonic acid "smoke acid").



Russian WAP - 1000 spray tank.

There were no Japanese exhibits. The most interesting exhibits were being sent to U.K. for further examination.

Bunkers and Outside Storage. The bunkers were of standard German construction. They were well ventilated, one at least being equipped so that a suction machine could be attached from the outside. Many of the bombs were empty but there were some filled, such as yellow ring, double yellow ring, green ring yellow, and white ring. A few 1800 kg. double white ring bombs were stored in the open.

Approximately thirty (30) 250 kg. bombs were grouped around an excavation adjacent to the two story brick building. These bombs had three green rings and were reputed to have contained Sarin, but to have been emptied and the Sarin destroyed with alkali. There were eight spray tanks, with green or yellow markings, marked S 500 located near this same building.

A number of shell apparently containing chargings undergoing storage test were found stacked in the open. A small building contained drums of such chemicals as sulphuric acid, ammonia solution, benzol, etc.

(C) Nebelfullstelle

The Nebelfullstelle lies within the wired compound of Raubkammer, surrounded by its own inner fence. The layout of the buildings is shown in Fig. XXVI.

The station was commanded by Hauptmann BAUMANN who was under the orders of Major ZANDU at Luna Ost. Under the OC (Anstalt Leiter) were a number of Feuerwerkers (all Sgt. Majors with one officer). Under the Feuerwerkers were civilian Werkmeisters. All the military staff had been evacuated.

The Nebelfullstelle was originally set up at Raubkammer with the idea of trying out experimental methods of charging as part of the chemical warfare development organisation. It was, however, quickly taken over for production purposes, and then comprised one of the five Army charging stations. The other four were Locknitz, St. Georgen, Dessau and Lübbecke (not completed).

It comprises filling plants, Store sheds, shell finishing plants, shell packing plants and 13 concrete earth covered shell store rooms. The earth covered store rooms and some of the buildings are camouflaged by vegetation growing over it but most of the ground sheds are not camouflaged. The following is a list of buildings with a brief note of their contents.

	Name	Description
1	Wache	Guard room and barracks
2	Geschz. Geb	Administrative Offices
3	Krankenrievier Baracke	first aid post and small hospital
4	Lokschuppen	Maintenance shop for small locomotives
5	W.2 Werkstatt	Vehicle workshop, general stores, battery charging, woodworking shop etc.
6		Open wooden shed, empty.
7	Baracke 2	Small barracks.
8	Loschwasser Entnahmestelle	Static emergency water tank, underground.
9	G.M.H.6. (Grosse Munitionshaus 6.)	15 cm. green ring.) 10.5 cm. green ring.) about 3000 shell.
10	G.M.H.7. Grosse Munitionshaus	5,000 Sp Bu " 37 - Two yellow rings.
11	G.M.H.8.	5,000 Sp Bu " 37 - Two yellow rings.
12	G.M.H.9.	5,000 Sp Bu " 37 - Two yellow rings.
13	G.M.H.10	31,000 Kg Azin (Adamsite) in steel drums German Adamsite Italian Adamsite

	Name	Description
14	G.M.H.11	70 x 200 gals. Clark I.
15	G.M.H.12	20 x 200 gals. Clark I. 30,000 Kg. Tormesit.
16	G.M.H.13	5,000 Sp Bñ 37 - One yellow ring.
17	G.P.Sch 3. (Grosser Packschuppen 3)	Contains: empty Sp Bñ 37 and 10.5 cm. white ring shell filled.
18	Lg. H. 4 Lagerhaus	Contains: Product 200 (Tormesit) - 65,000 Kg. Tormesit - 15,500 Kg. 1,000 litre transport tanks - 83
19	M.A.H.3. Munitions Arbeitshaus	For preparation of shell. Contains a few partly filled white ring shell.
20	G.P. Sch.4. Gross Packschuppen 4	Many empty boxes for Sp Bñ 37 and other empty containers. Also Polystyrol III - 160 barrels.
21		Transformer and power house. Blown-up.
22	Fñllh. 2 (Fñllhaus 2)	Two filling machines for 15 cm. Nebelwerfer. Four filling machines for 10.5 and 15 cm shell. 4 x 20,000 litre tanks empty.

	Name	Description
23	M.A.H. 2 (Munitions Arbeitshaus)	Finishing shell after filling, i.e. detector paint, vacuum test, drying, painting, markings, head filling, fuzing, boxed.
24		Timekeepers or foremans office
25	G.P.Sch.2.(Grosser Packschuppen 2)	Empty packing boxes, discs, etc.
26	Waage 2	Weigh House
27	Entg. Geb. 1 (Entgiftungs Gebäude.)	Elaborate personal decontamination layout. Respirator testing and repairs to respirators and A/G clothing.
28	V.St. Verteilerstation	For offloading bulk supplies of war gases and transfer to storage tanks. 3 x 20,000 litres, filled mustard.
29	Pump. H. 2	Pumping station
30	Entg. Geb. 2 (Entgiftungs Gebäude 2).	Decontamination of 1,000 1. transport tanks. Small laboratory.
31	T. St. (Tetra- Station)	Storage of solvents.
32	B 5	Underground bunker, containing solvents.

Name	Description
33 B 6	Underground storage of mustard in eight 450,000 litre tanks, 7 filled mustard 1 empty.
34 Löschwasser Entnahmestelle 2	Static water supply, underground.
35 Lg. H. 3 (Lagerhaus)	Workshop 400 x 1,650 Kg. Italian H containers, some filled 1 filling machine, not installed.
36 Waage 1	Weigh House
37 Lg.H. 1 (Lagerhaus)	General stores including protective clothing, steam and pipe fitters stores, machinists supplies.
38 G.M.H. 5 Grosse Munitionshaus	15 cm. green ring shell } about 3000 10.5 cm. green ring shell }
39 G.M.H. 4	3,000 rounds 15 cm. one green ring.
40 G.M.H. 3	5,000 Sp Bu 37 - two yellow rings.
41 G.M.H. 2	5,400 - Sp Bu 37 - two yellow rings.
42 G.M.H. 1	1,000 x 20 Kg. Italian CAP in barrels. 6 barrels solid CW agent (Italian) 20 barrels liquid CW agent (Italian)
43 Abort	Latrine

	Name	Description
44	H.M.H. Munitionshaus	Small storage of exploders, fuzes, etc.
45		Canteen and locker rooms
46	Entg. Geb. 3 (Entgiftung, Gebäude 3)	Personal decontamination only.
47a	G.P. Sch.1. (Grosser Packschuppen 1)	Storage of empty components, mostly 15 cm. Nebelwerfer, (about 40,000). Some shell.
47b	M.A.H. 1 (Munitions Arbeitshaus 1)	For preparation of projectiles prior to filling.
48	Heiz. (Heizung)	Boiler house and heating plant, etc.
49	Schalth. (Schalthaus)	Valve control house.
50	Lg. H. 2 (Lagerhaus 2)	Earthenware stores and general salvage.
51	Fullh. 1 (Fullhaus 1)	Two automatic charging machines with complete charging plant.
52		Open wooden shelter shed
53	Loth. (Lothaus)	Welding plant.

	Name	Description
54	Pump. H.1. (Pumpenhaus 1)	Pumping station
55	F. Ger. Sch. 1 (Feuerlöschgerät Schuppen).	Fire apparatus
56	B. 8	Empty bunker
57	B. 3	Bunker for inflammable liquids

The following notes supplement the information given in the above list.

Füllhaus 1. Filling house 1 contained two automatic filling machines used for filling 10.5 cm. and 15 cm. artillery shells and 10 cm. mortar shells. The machines were made by Hagemuk at Kiel, and were reported to have been installed about a year ago. These machines were installed as reserve to the charging machines in Filling House 2.

Twelve intermediate storage tanks were installed under the floor below the filling machines. These tanks were each equipped with two mixers. O and A were mixed together in these tanks. Six tanks were connected to each filling machine.

Füllhaus 2. Filling house 2 contained two semi automatic rotary filling machines used to fill 15 cm. Nebelwerfer rockets and four semi automatic rotary machines used to fill 15 cm, 10.5 cm artillery shells and 10 cm mortar shells. These machines were made by Gebrüder Schaffler. These machines filled munitions with ZÄHLOST from 1940 until 1942. This caused the machines to corrode and therefore the filling of ZÄHLOST was discontinued. Since then munitions were filled with A, O and OA. It was reported that the rockets were filled within the past eighteen months.

This house employed thirty five men from which approximately three minor casualties occurred per day. No serious casualties had occurred.

Layout of Shell Charging Plant at the Nebelfüllstelle

A brief description of the charging layout is as follows :-

Empty munitions were brought on railway wagons and off loaded into empty munitions store attached to Munitions Arbeits Haus No.I - and stored in stacks of approximately 2,000, the total present stock being estimated at 100,000, comprising 10.5 and 15 centimetre shell and 15 centimetre rocket heads. A very efficient overhead conveyor system runs around this store and the empty munitions were loaded on this conveyor and transferred into the next room where they are off loaded and placed on a table conveyor, fitted, at approximately 2' 6" intervals with vices. The munitions were inspected to ensure that they were complete and ready for filling. From this conveyor the weapons were passed by an underground conveyor system to Fullhaus 2, where the conveyor emerges at ground level alongside the charging machines. The munitions are offloaded, placed in the requisite vice for charging and sealing on the charging machine. After this the munitions are placed on an underground conveyor, and transferred to Munitions Arbeits Haus No.II. Here they were painted with detector paint at the sealing plug and welded joint between the nose and body. They were next loaded onto small trucks holding approximately 100 weapons and three of these trucks were placed into a vacuum oven for test for leakers. They remained in this oven for about one hour, when they were removed and placed on a conveyor, nose down on a spigot and passed through a drying oven electrically heated. On emerging from the first pass through this oven, the shell rotated and was touched up with paint from a spray gun and returned through the oven and back again when they were completely dry. This conveyor now passed through a hole in the wall into the next room where they were off loaded and placed in a vice on a table conveyor. Here they were head filled and fitted with a fuze, continuing along the conveyor to a check weighing machine, and if they passed inspection here, they were transferred to another table conveyor and finally placed in their transport box ready for despatch to Muna Ost, whence they were sent to Dithlingen for head filling with HE.

The general layout, convenience of handling weapons and the dispositions of the buildings are considered to have been very efficient.



M.A.H.I. Nebelfullstelle
Empty Weapons Store
10.5 cm Shell
15.0 cm Shell
15.0 cm Rocket Heads.



M.A.H.I. Nebelfullstelle
Examination of Empty Weapons.
Entrance of Underground Conveyor
Shewn Extreme Left



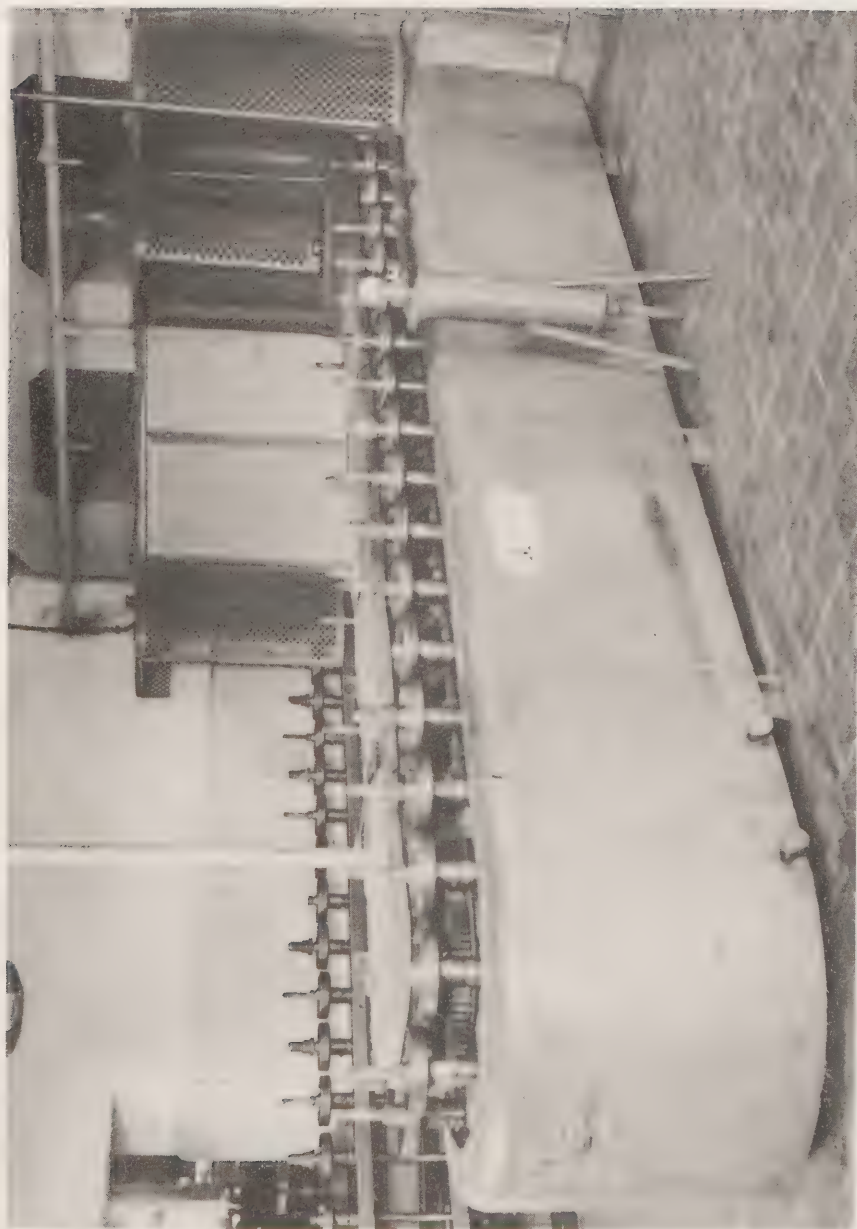
Füllhaus 2 - Nebelfüllstelle
Overhead Conveyor Shewn on Right of Machines
4 Semi Automatic Charging and Sealing Rotary Machines
in Line.



Nebelfullstelle
Semi Automatic Rotary Charging and Sealing Machines
Manufactured by Gebruder Schaffler, Berlin.



M.A.H.II - Nebelfullstelle
Overhead Conveyor on Right Emerging from Underground.
2 Vacuum Ovens for Leak Test. Showing Empty Truck on Right.
Truck in Vacuum Oven which is Ready for Closing.
The 2 Ovens are used Alternately.



M.A.H.II - Nebelfullstelle
Emerging End of Hot Air Oven Shewing First Line of Conveyor
Emerging, Continuing Back into Oven and Finally Emerging
Against Hole in Wall.

Note :- Paint Spray Equipment in Foreground.



M.A.H.II - Nebelfüllstelle.
Table Conveyor Fitted with Vices for Head Filling,
Fuze Fitting and Finally Check Weighing.

Investigation of Chemical Warfare Targets in
the Munsterlager Area, Including Raubkammer

APPENDIX V.

Production Development

1. Introduction.
2. Organisation of Staff at R VIII Raubkammer.
3. Description of Site.
4. Description of Sarin Pilot Unit.
 - (a) Raw materials and Intermediates.
 - (b) Brief outline of Chemistry of each stage.
 - (c) Plant yield and output.
 - (d) Details of plant.
 - (e) Analytical Methods.
 - (f) Safety precautions.
 - (g) Destruction of Stocks of Sarin.
5. Description of Excelsior Pilot Unit.
 - (a) Raw materials and Intermediates.
 - (b) Outline of Chemistry of Process.
 - (c) Plant yields and output.
 - (d) Details of plant.
 - (e) Safety precautions.
6. Miscellaneous
 - (a) Information regarding Sarin not yet obtained but believed to be available.
 - (b) Production plans for Sarin.
 - (c) Equipment of special interest at R VIII
 - (d) Equipment removed for examination.
 - (e) Chemicals removed for examination.
7. The Manufacture of Tabun at Raubkammer.
8. C.W. Production in Germany.
9. Conversion of Mustard Gas to commercial products.

1. Introduction

The control of all research and development on the production of chemical warfare agents was in the hands of Group VIII of Wa Prüf 9, headed by Min.Ral. Dr.van der Linde, assisted by Dr. Gebhardt. The actual research work was carried out either by the firms engaged on production or by the research institutes F1, F2 and F3 at Spandau. The preliminary technical development work was carried out in laboratory VIII L, Spandau, the head of which was Dr. Dörken. Plant development was carried out either by firms, or by Bereich R VIII at Raubkammer (sometimes known as Heidkrug).

This Appendix is mainly concerned with the activities which had been proceeding in recent years at R VIII, Raubkammer, since ample information on production research and development proceeding elsewhere is obtainable at other targets. It does however, include a note on unsuccessful attempts to convert mustard gas into plastics or other useful materials, and a table showing the scheduled rates of production of war gases at various factories.

It was possible to erect and test at R VIII Raubkammer units having a capacity of up to 10 tons per week.

The design of these units erected at Raubkammer were carried out by a chemist (Gebhardt) assisted by an engineer (Schneidewind) both operating normally in Berlin. The chemists on the plants were plant operators who acquired a knowledge of the design from actual operational contact, and who often suggested modifications of the design to their superiors.

Research projects were normally under direction of Dr. Reetz at Spandau but it would appear that subsequent to disorganisation at Spandau certain work was carried out by individuals at Raubkammer, e.g. Engineer Artelt was responsible for laboratory development of Excelsior.

Two processes have been developed and pilot units erected. These are the Excelsior and Sarin units - details of which are given later.

The building at present housing the Excelsior plant was used some years ago for the development of Tabun. Information on the method used will be found below.

Raw materials for these production items were obtained from other state factories or the I.G. and final products were despatched to other sites for safe storage.

In the case of Excelsior the intermediate known as Merodan was obtained from I.G. (Mainkur) and in the case of Sarin the intermediate A3, was obtained from Dyhernfurth.

The Excelsior plant produced some 10 tons of good product which is now stored in a Salt Mine near Bugdorf, together with some 50 tons of merodan.

Only $\frac{1}{2}$ ton of Sarin was produced during the development work on the unit and this was destroyed by the Germans prior to occupation by British troops.

It should be noted that the development facilities at Raubkammer were very limited. Only two buildings on the site were equipped for chemical production and as far as can be ascertained there appeared to have been no programme for the erection of new process houses for the development of any further chemical process.

With regard to the increased production of the two C.W. agents developed at Raubkammer there appears to be no project for an increased capacity for Excelsior, but it has been stated that it was proposed to increase the production of Sarin to some 600 tons per month, the production plants being erected at Dyhernfurth and Falkenhagen.

The following were interrogated during the compilation of this Appendix.

Min.Rat Dr. van der Linde	-	Head of Group VIII Wa Prüf 9.
Dr. Stadler	-	VIII L Spandau.
Dr. Schusteritz	-	VIII L Spandau.
Dr. Fahrenholtz.	-	Head of R VIII, Raubkammer.
Dr. Rudolph Jannsen	-	R VIII Raubkammer.
Dr. Killinger	-	" "
Dr. Richter	-	" "
Dr. Heinz Artelt	-	" "
Dr. Poeller.	-	" "
Spengler	-	" "

2. Organisation of Staff at R VIII, Raubkammer

The most important of the staff at R VIII were as follows:-

<u>Fahrenholtz</u>	-	a chemist in charge of R VIII but largely engaged on administrative duties.
<u>R. Jannsen</u>	-	deputy to Fahrenholtz and in charge of Sarin development. Chemist.
<u>Artelt</u>	-	in charge of Excelsior development. Chemical Engineer.
<u>Schusteritz</u>	-	A chemist on loan from Spandau and engaged on Sarin plant development.
<u>Poeller</u>	-	ditto -

The development work seems to have been largely controlled by Dr. Gebhardt, a chemist in Group VIII of Wa Prüf 9 who frequently visited Raubkammer. Engineering drawings were prepared by Scheidewind, an engineer on Gebhardt's staff.

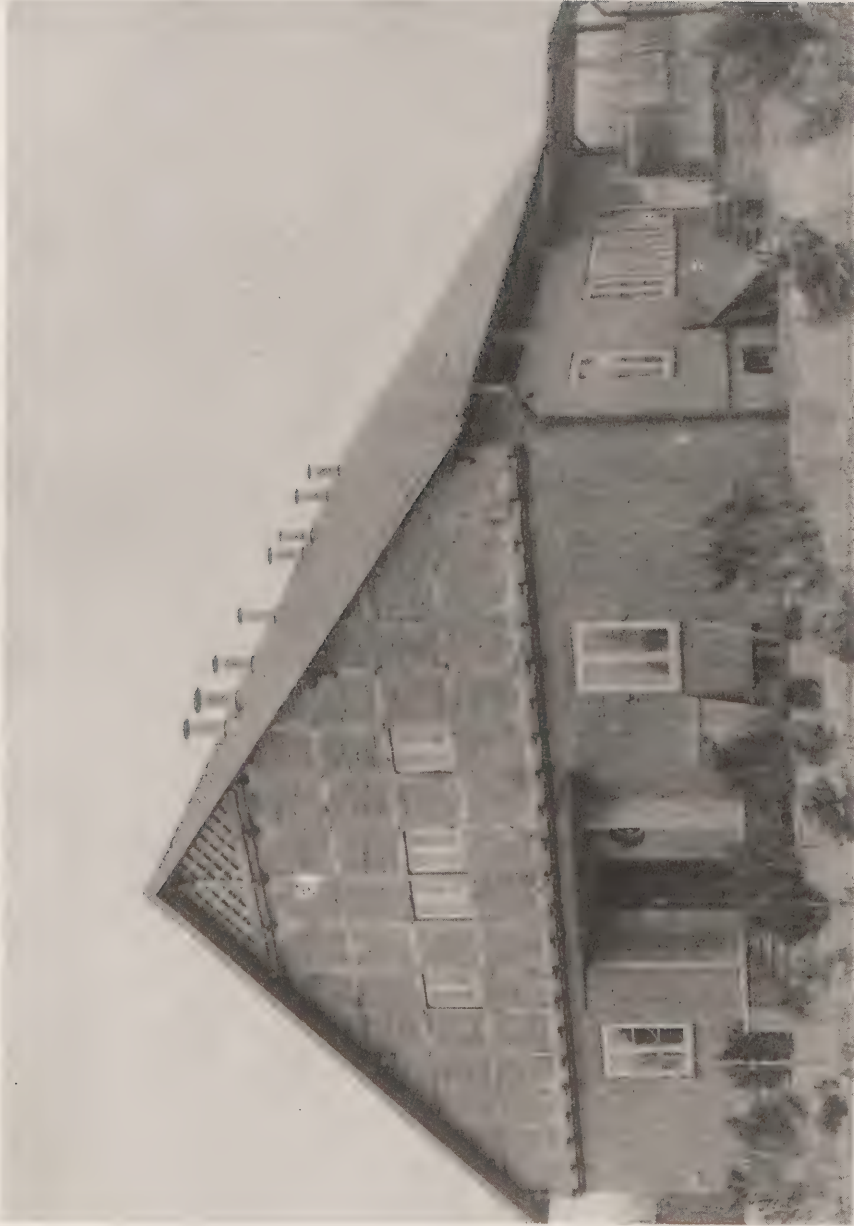
3. Description of Site

Figure I shows the disposition of various buildings. The important buildings present externally the appearance of the large farm buildings typical of the district and are spread well apart. Building A, contains a number of well appointed labs and the offices of Fahrenholtz and Artelt. There is also a well stocked apparatus store in house A. House C contains the Excelsior plant and House Cl the Sarin unit and the offices of Jannsen, Schusteritz and Poeller. There is also a drawing office used by Schneidewind in this building. There is a large well stocked equipment store for fittings, valves, pumps, glass lines, electrical equipment etc. and another store for larger equipment such as enamelled reaction vessels, and for steel sheet, angles etc. and lead sheet and pipe.

Electric power and water are supplied to the site. Steam is generated on the site.



General view of R VIII Shewing Railway and Houses 'A' and 'C' together with Auxiliary Buildings.



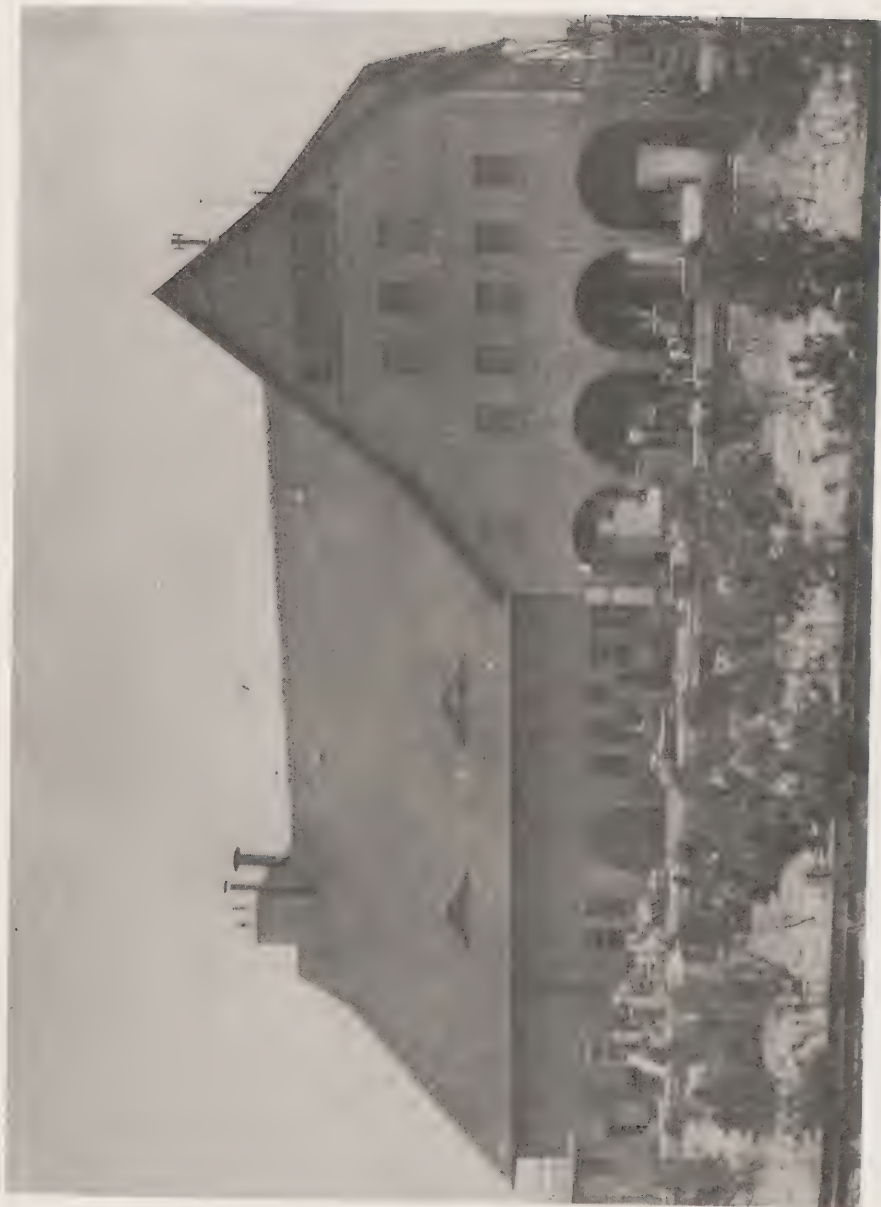
R VIII - House 'A'
Process Laboratories, Stores and Offices.



R VIII House 'C'. (Excelsior Building)
View from the North.



F VIII - House 'C1' (Sarin Building)
View from South East.



R VIII - House 'C1' (Sarin Building).
View from North-West.



R VIII - Sarin Plant.
Foreground - Ventilating Shafts from the Underground
Storage cellars.
Background - House 'H' containing nickel storage
vessels.

4. Description of the Sarin Pilot Unit

The description given below is based on inspection and examination of the plant, on information derived from drawings found in an near C1 building, and on information supplied by Jannsen, Schusteritz and Poeller (together with a small amount of information supplied by Spengler and Killinger, two subordinate members of the staff). No written reports or memoranda have so far been found. Neither Fahrenholtz nor Gebhardt have been located, which is particularly unfortunate since Gebhardt is probably the only man who knows the full story of Sarin development.

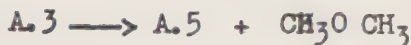
(a) Raw Materials and Intermediates (See also Fig.II).

<u>Code Letter</u>	<u>Formula</u>	<u>Supplier</u>	<u>S.G.</u> <u>20°C.</u>	<u>M.P.</u>	<u>B.P.</u> <u>(approx)</u>
A.2.	$(\text{CH}_3)_2\text{CHOH}$	Rhein Prussen Ruhr.			
A.3.	$\text{O} = \text{P} \begin{array}{l} \nearrow \text{H} \\ \searrow \text{OCH}_3 \\ \text{OCH}_3 \end{array}$	Dyhernfurth.	1.95	<0°C.	90°C. at 30 mm.
A.4.	$\text{O} = \text{P} \begin{array}{l} \nearrow \text{CH}_3 \\ \searrow \text{OCH}_3 \\ \text{OCH}_3 \end{array}$	Spandau	1.165	<0°C.	
A.5.	Mixture of $\text{O} = \text{P} \begin{array}{l} \nearrow \text{CH}_3 \\ \searrow \text{OH} \\ \text{OCH}_3 \end{array}$ and $\text{O} = \text{P} \begin{array}{l} \nearrow \text{CH}_3 \\ \searrow \text{OH} \end{array} \begin{array}{l} \text{CH}_3 \\ \text{HO} \end{array} \text{P} = \text{O}$ $\quad \quad \quad \text{O} \quad \quad \quad$	} Intermediate made at R.8.	Solid at ordin- ary temps.	130- 150°C.	Not distill- able.
containing about 4 mols of latter to 3 mols of the former.					
B.1.	PCl_3	Dyhernfurth.			

<u>Code Letter</u>	<u>Formula</u>	<u>Supplier</u>	<u>S.G. 20°C.</u>	<u>M.P.</u>	<u>B.P. (approx)</u>
B.2.	POCl_3	By-product of Sarin manufacture at R.VIII.			
B.3.	$\text{O} = \text{P} \begin{array}{l} \diagup \text{Cl} \\ - \text{Cl} \\ \diagdown \text{CH}_3 \end{array}$	Intermediate made at R.8	1.46	33°C.	95°C. at 70 mm. Hg.
B.4	Equimolal mixture of				No defin- ite B.P. Since sub- stance is a mixture.
	$\text{O} = \text{P} \begin{array}{l} \diagup \text{Cl} \\ - \text{Cl} \\ \diagdown \text{CH}_3 \end{array}$ and	"	1.38	<0°C.	
	$\text{O} = \text{P} \begin{array}{l} \diagup \text{F} \\ - \text{F} \\ \diagdown \text{CH}_3 \end{array}$				
C.2	HF	Riedel, Hanover. Schering, Berlin.			
E(Sarin)	$\text{O} = \text{P} \begin{array}{l} \diagup \text{CH}_3 \\ - \text{OC}_3\text{H}_7 \\ \diagdown \text{F} \end{array}$	Final pro- duct at R.8.	1.11	<0°C.	65°C. at 30 mm Hg. 150°C. at 760 mm Hg. (with some de- composi- tion).

(b) Brief Outline of Chemistry of each stage

Stage I.



240 - 300°C.

The reactions involved are complex and small quantities of PH_3 , P_2H_4 and CH_4 are evolved in addition to CH_3OCH_3 . This stage is a very recent addition to the process.

Stage II.

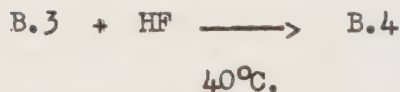


This was originally the first stage at R.VIII (prior to the installation of the plant for converting A.3 to A.5).

Stage III.

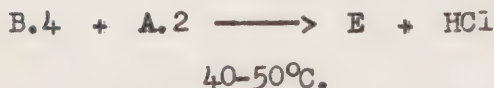
Separation of B.2 and B.3 by vacuum distillation. B.3 requires to be at least 95 per cent pure.

Stage IV.



One half mol of HF is used per mol B.3.

Stage V.



The crude E is stripped of HCl under vacuum, distilled under vacuum, ammonia treated and filtered.

(c) Plant yield and output

Rated output = 50 tons month stabilised E. Less than 1 ton E has been produced in the plant and the plant has never operated as a whole, i.e. all 5 stages have never operated simultaneously.

The second stage was the first to be operated (in April 1944) using A.4, B.1 and chlorine. Operation of this stage was however of short duration because of failure of the distillation section (B.2/B.3) necessitating a radical alteration in the plant which took many months. On completion of the new type of still in March 1945 the second stage was again operated using this time A.5 + B.1 + Cl₂. The apparatus for producing A.5 was operated in all for about 120 hours, the second stage in all for about 12 days (including the first period using A.4) and the redesigned still for about 14 days. The fourth stage ran for a few hours only. It is obvious from all this that no reliable estimates of yield or probable rate of output can be given. All the witnesses however appear to think that a very great deal more work would be required before an output anywhere approaching 50 tons/month would be realised. The yields quoted below are indicative of what could reasonably be expected (on the basis of yields obtained semi-technically at Spandau) after prolonged operation of the unit at R.VIII.

Stages	(A.4 ———>	B.3	about 75 per cent.
1, 2 and 3.	(A.3 ———>	B.3	about 70 per cent.

Stages	(B.3 ———>	E	about 80 per cent.
4 and 5.			

i.e. overall yield A.3 ———> E of the order of 50 per cent.

It is quite likely that this figure is optimistic, at any rate as regards possible results from the unit as set out at present.

(d) Details of Plant

This section deals briefly with the general arrangement of the vessels and services and touches briefly on points of special interest. No attempt is made to set forth all the detail which has emerged from various discussions and interrogations. This detailed information will be studied later in conjunction with the plant drawings which have been found and will form the basis for a design memorandum (which, however, will necessarily be incomplete unless and until documentary evidence is found or information is obtained from Dr. Gebhardt).

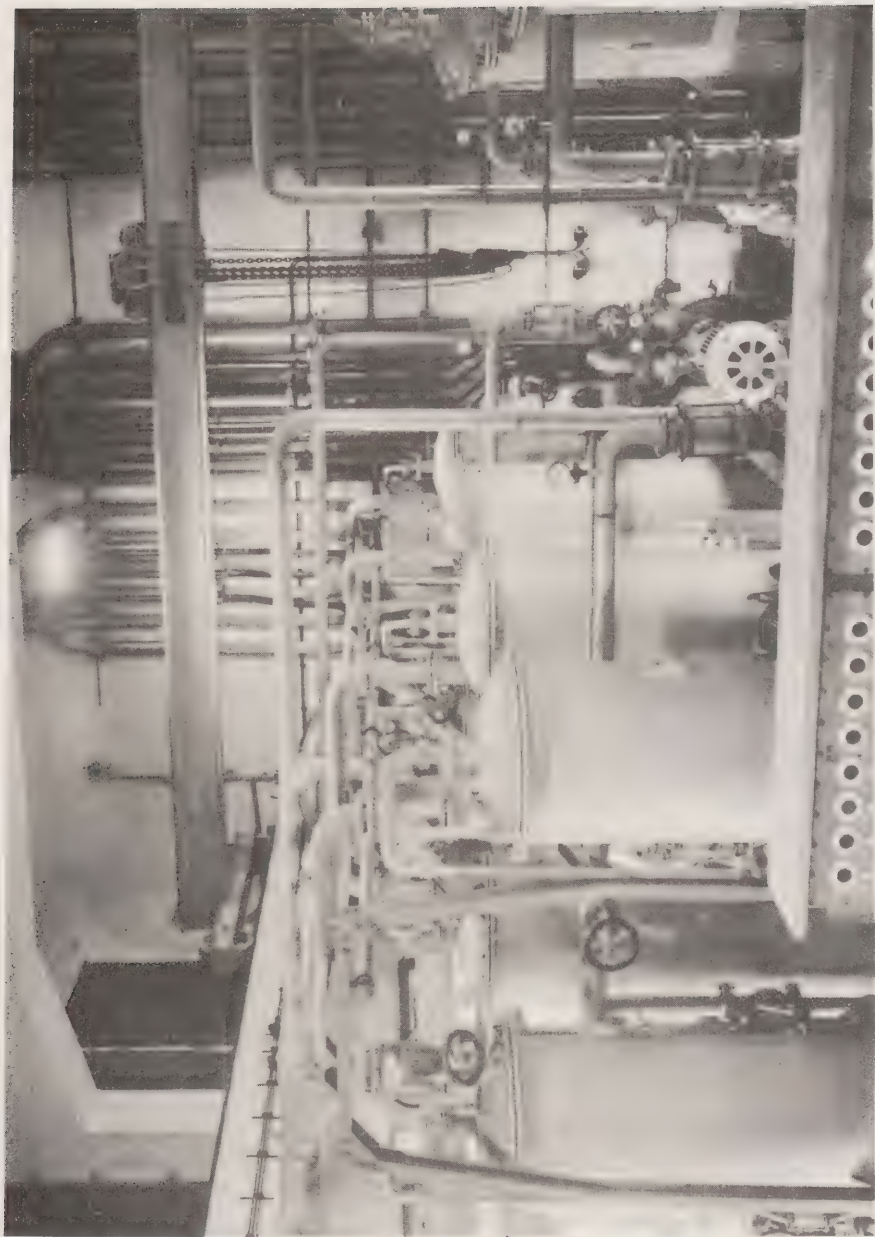
The following should be read in conjunction with Figs.II, III and IV., and with the photographs.

(i) General Arrangement

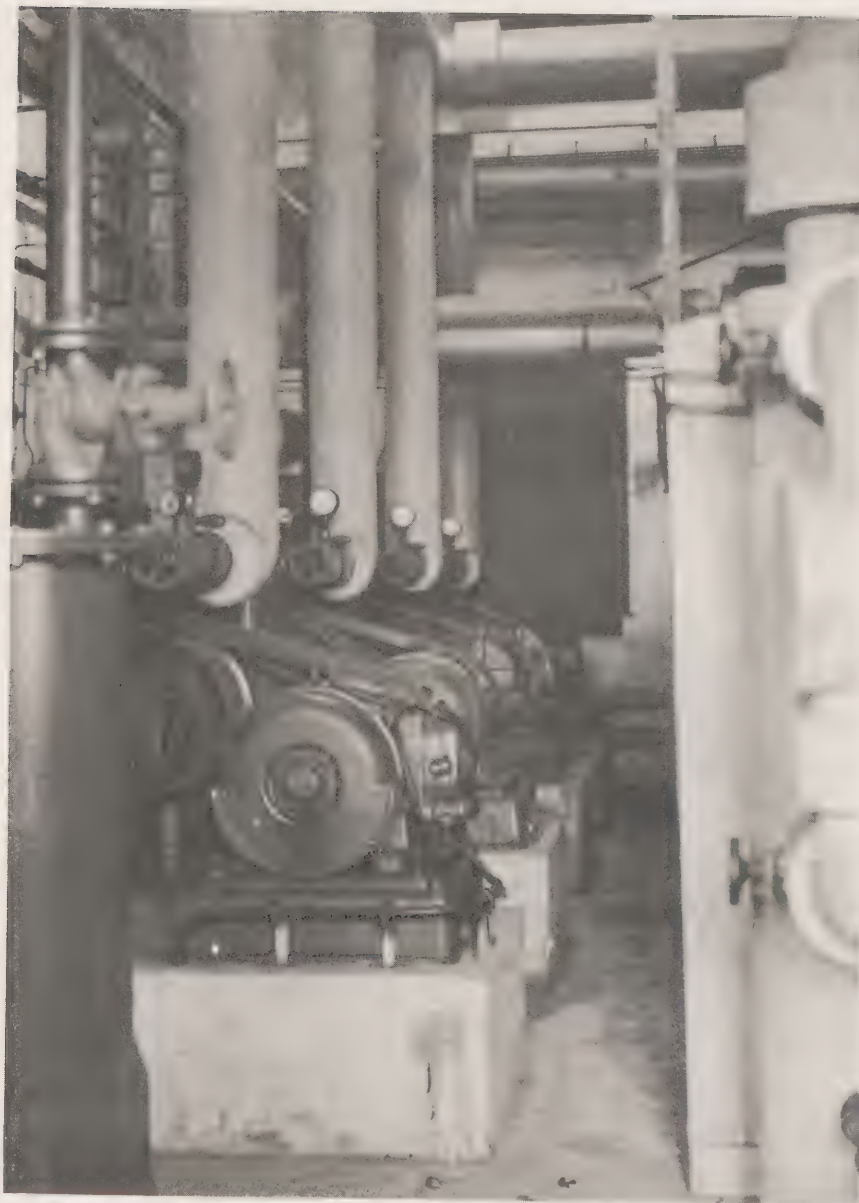
The reaction vessels are housed in a building about 100' x 40' which was completed in 1940 and was intended to be a general plant building. It has been used only for Sarin however. In 1942 a wing containing vacuum pumps, compressors, and a refrigerating machine was added.

A large underground storage cellar was also added, to contain sufficient storage space for various raw materials and intermediates so that it would be possible to keep any stage running for a month independently of other stages or of supplies of raw materials from outside. The newer part of the building including the underground storage and some offices appears to be well laid out but the original building containing the reaction vessels and some intermediate storage vessels is very congested and the arrangement of the vessels is far from ideal.

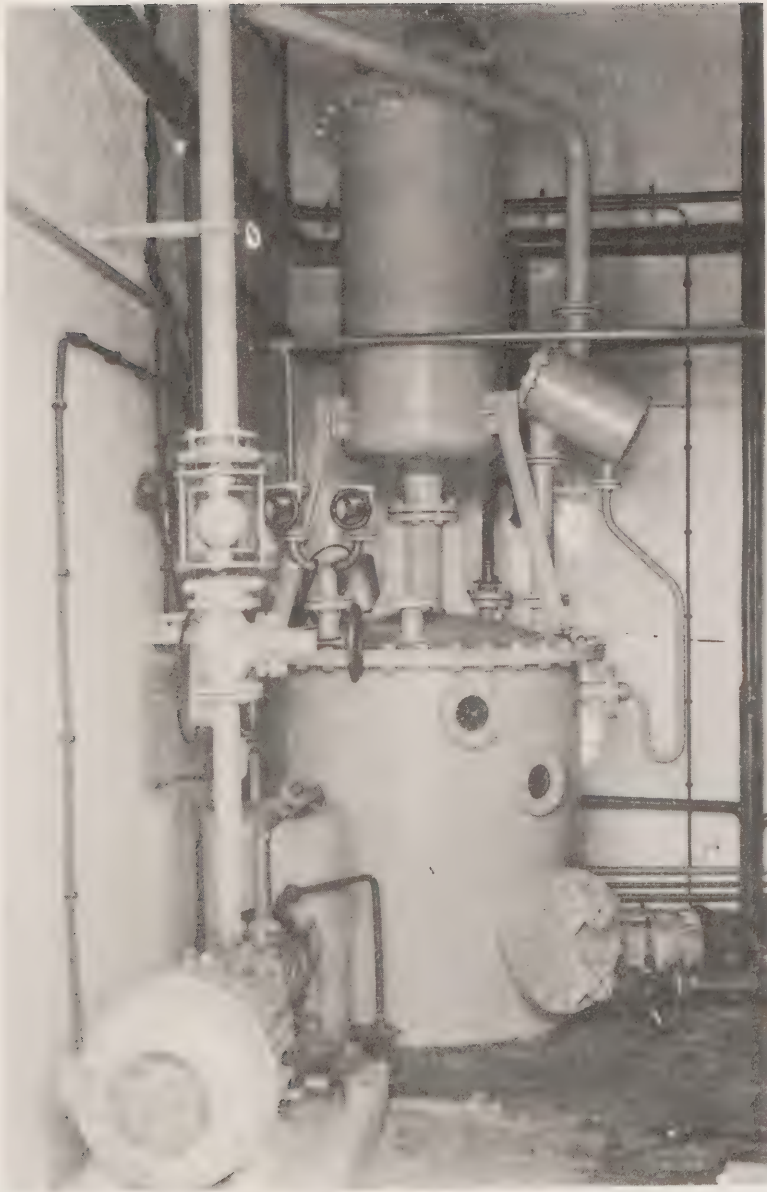
Steam is supplied to the building at 3 atmospheres and also at low pressure. Compressed air is obtained at two pressure (3 and 15 ats.) from compressors in the compressor house mentioned above. This house also contains 12 rotary vacuum pumps each equipped with a caustic soda scrubbing system. Calcium chloride brine is cooled to about - 15°C by four ammonia compressors (Linde) also situated in the compressor house.



Sarin Plant.
Vacuum Pumps and Scrubbing Towers.



Sarin Plant.
Ammonia Compressors.



Typical arrangement of a
Vacuum Pump with Ancillary Scrubbing system.

Transfer of liquids throughout the building and to and from main storage is normally effected for Group A compounds by pumping, for Group B by air pressure, for Group C by air pressure (high pressure required - 8 ats or more) and for E by suction.

Aqueous plant effluents are collected in a sump and pumped 200-300 yds. to a brick lined treating pit where lime is added. The neutralised effluent then flows to an unlined pit where the liquid seeps into the earth. The system appears not to have worked very well, suffering from a quite usual fault viz. the sump for collecting the effluent is neither big enough nor deep enough.

Operation of the plant was handicapped by shortage of water. In an attempt to overcome this the used cooling water was pumped to an underground reservoir and then recycled to the plant. This scheme was not a success since no water cooler was put in the circuit and adventitious cooling was inadequate.

The whole plant is provided with forced ventilation. General ventilation in the plant building is provided by 3 large air heaters which blow air into the building through a number of ducts, the air being extracted from the base of the building through charcoal filters. Special parts of the plant, e.g. the E reaction and distillation section are provided with special fans, the discharge from which is scrubbed by caustic soda. The underground storage cellar is provided with a separate forced ventilation system.

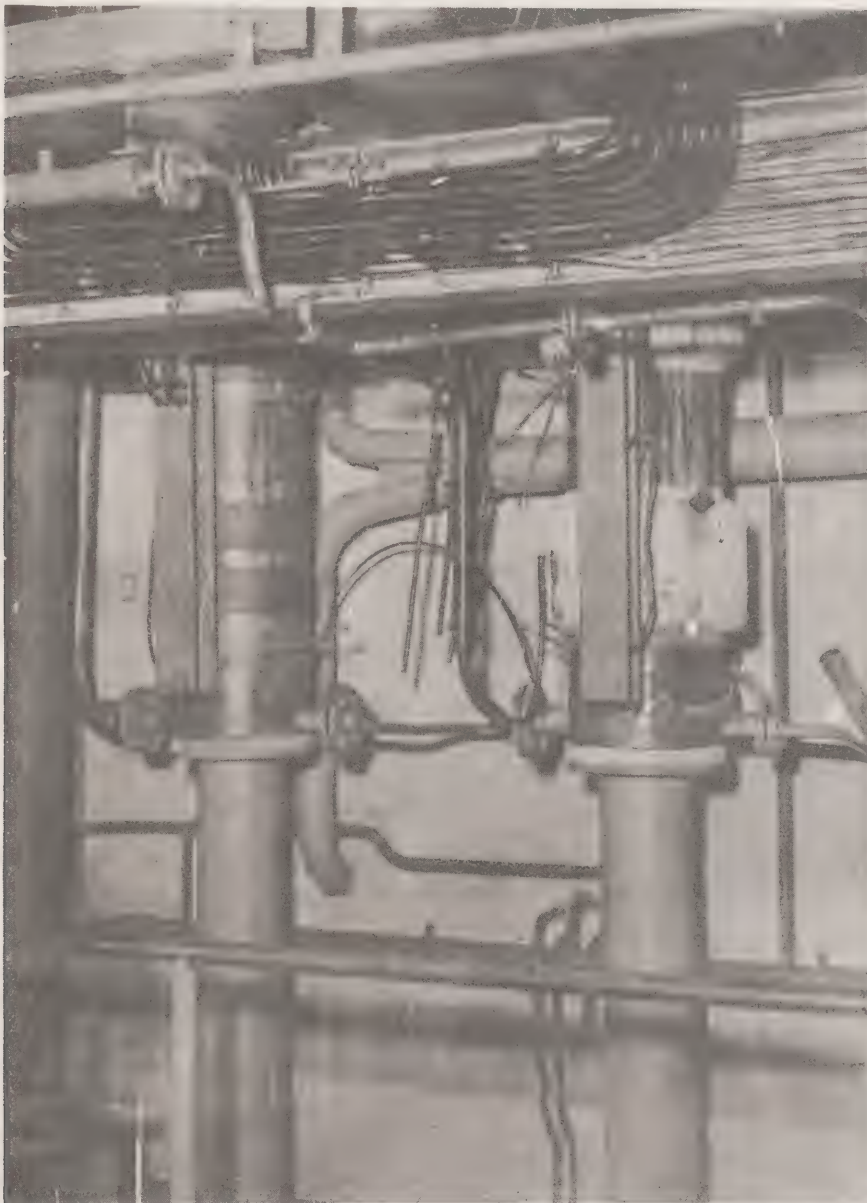
Analytical process control was carried out in the laboratory situated in the plant building. A second laboratory was nearly completed.

(ii) Arrangement of Individual Stages

1st Stage

A.3 is pumped from stoneware lined tanks outside C.I. building to a nickel head tank. It then flows at about 110 l/hour to a silver apparatus consisting of two vertical tubes, heated externally by electric strip heaters, connected by a horizontal tube. The liquid flows up the first tube and down the second tube. The apparatus is provided with a shell and tube reflux condenser (silver tubes) cooled with water and a similar type of condenser cooled with brine). Temperature in

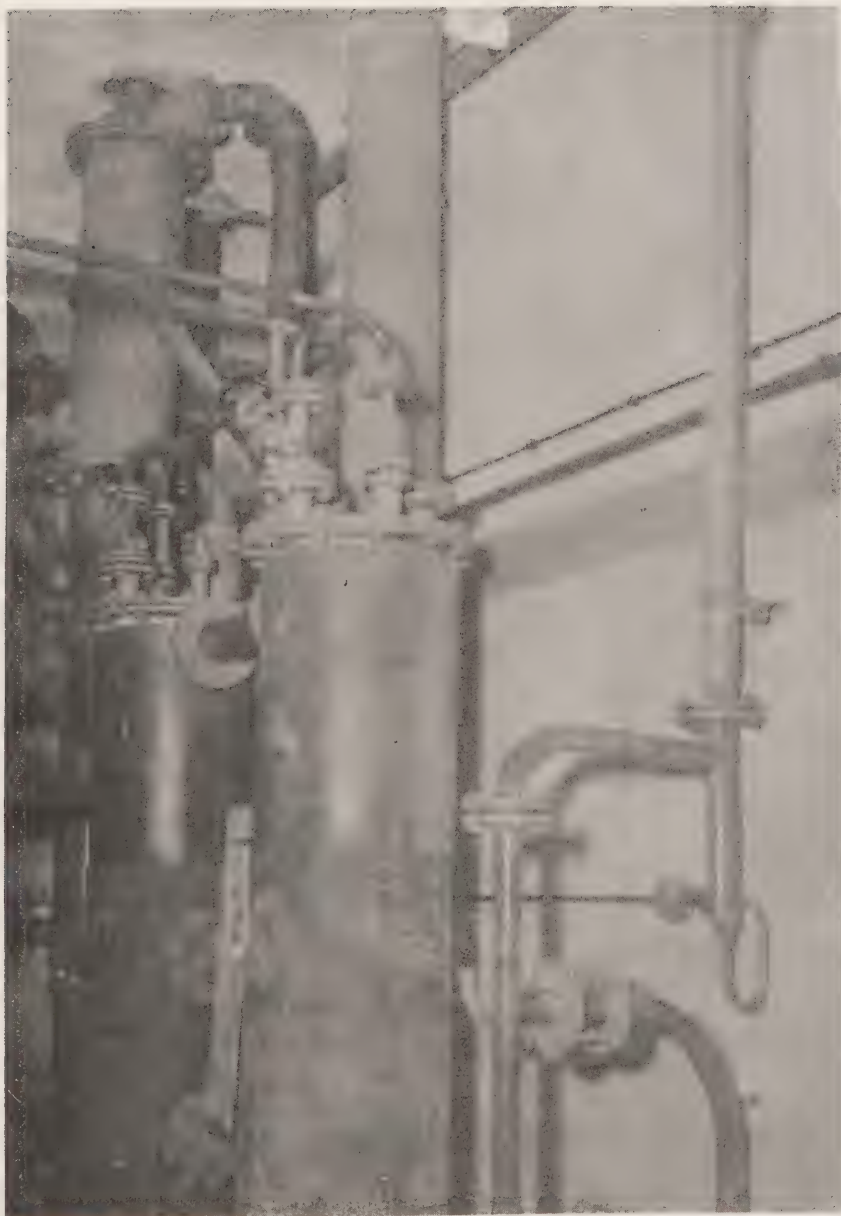
the first limb is maintained at 245-260°C and in the second limb 250-300°C. During operation both limbs are continuously purged with nitrogen and the gases evolved (CH_3OCH_3 with small amounts of PH_3 , P_2H_4 and CH_4) are burnt at the base of a vertical steel chimney. The silver used for this plant contains about 1 per cent Beryllium and there are two units, one working and one spare. One of these units has been dismantled ready for despatch to England.



Sarin Plant.
A3 to A5 Conversion Unit. 2nd Floor.



Sarin Plant.
A3 to A5 Conversion Unit. 3rd Floor.



Sarin Plant.
A3 to A5 Conversion Unit. 3rd Floor.

The plant requires careful temperature control as the reaction tends to go with explosive violence if the temperature exceeds 300°C . Furthermore oxygen must be carefully excluded to avoid formation of explosive mixtures with CH_3OCH_3 and phosphine. In practice control was fairly simple at half load (50 l/hr.) but much more difficult at full load. The existing plant would not be capable of keeping the reaction under control if the apparatus were started up using A.3 only and it is necessary to start up using A.5 containing only a small proportion of A.3. This limitation appears to be due to the relatively small cooling surface/volume ratio since pure A.3 can be used to start up small scale apparatus.

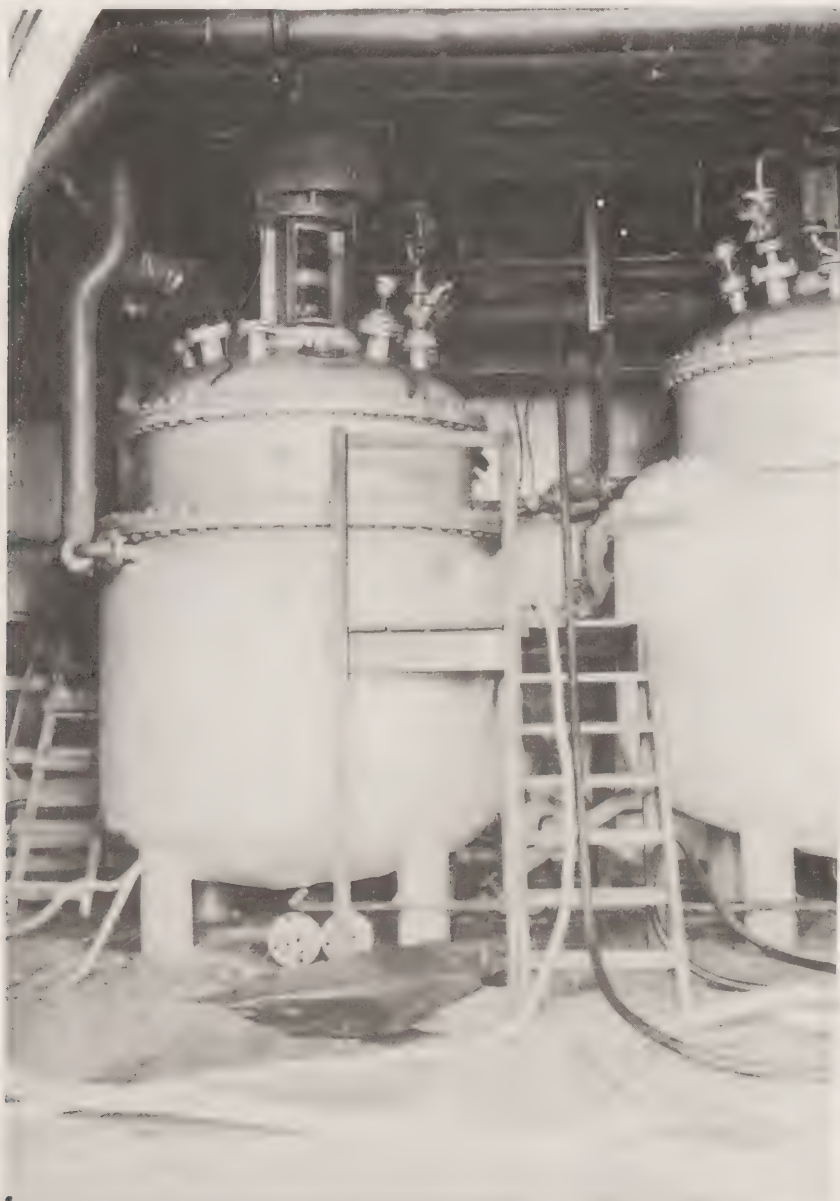
The quality of the A.3 supplied from Dyhernfurth was variable (A.3 was made by continuous addition of PCl_3 to CH_3OH in CH_3Cl solution, the CH_3Cl being continuously sucked off, compressed and returned to the apparatus, thereby maintaining the reaction temperature at $0^{\circ} - 10^{\circ}\text{C}$) and this increased the difficulties of the conversion to A.5).

The yield of A.5 from A.3, as measured by the organic P content of the two compounds, was about 90 per cent under the best operating conditions.

2nd Stage.

The product from the 1st stage is fed direct (without measurement) into a stirred homogeneously lead lined vessel (about 500 galls capacity). Equivalent quantities of B.1 and chlorine are added (about 200 l/hr. B.1 and 160 Kg/hr Cl_2 , but this varies somewhat with the composition of the A.5). Over chlorination is indicated by a green colour accompanied sometimes with formation of a green precipitate. The original method of operation utilised A.4 instead of A.5 and uniform results were then more readily obtainable. Reaction temperature is maintained at 60°C by jacket cooling (brine). The reaction product overflows continuously to a steam jacketted homogeneously lead lined stirred vessel of 500 galls capacity where the temperature is raised to 100°C . The reaction product (B.2 + B.3) overflows to a lead lined storage tank. This material contains about 72 per cent B.2, 25 per cent B.3, $1-1\frac{1}{2}$ per cent residue and 1-2 per cent dissolved HCl . Both the HCl and CH_3Cl evolved

during the reaction pass via lead reflux condensers (water cooled) and glass lines to an HCl scrubbing tower from which the HCl free CH_3Cl proceeds to a steel gasometer. From the gasometer the CH_3Cl is drawn to a sulphuric acid drying tower and is then compressed in a Linde compressor. During the very limited time of operation of Stage 2 this CH_3Cl compression system failed to function satisfactorily (it was not possible to obtain gaseous CH_3Cl sufficiently free from air). The intention was to utilise the recovered CH_3Cl for A.3 manufacture (see earlier). Chlorine used for this stage is vaporised by conventional type of vaporiser.



Sarin Plant.
Chlorination of A4 or A5 - 1st Floor.

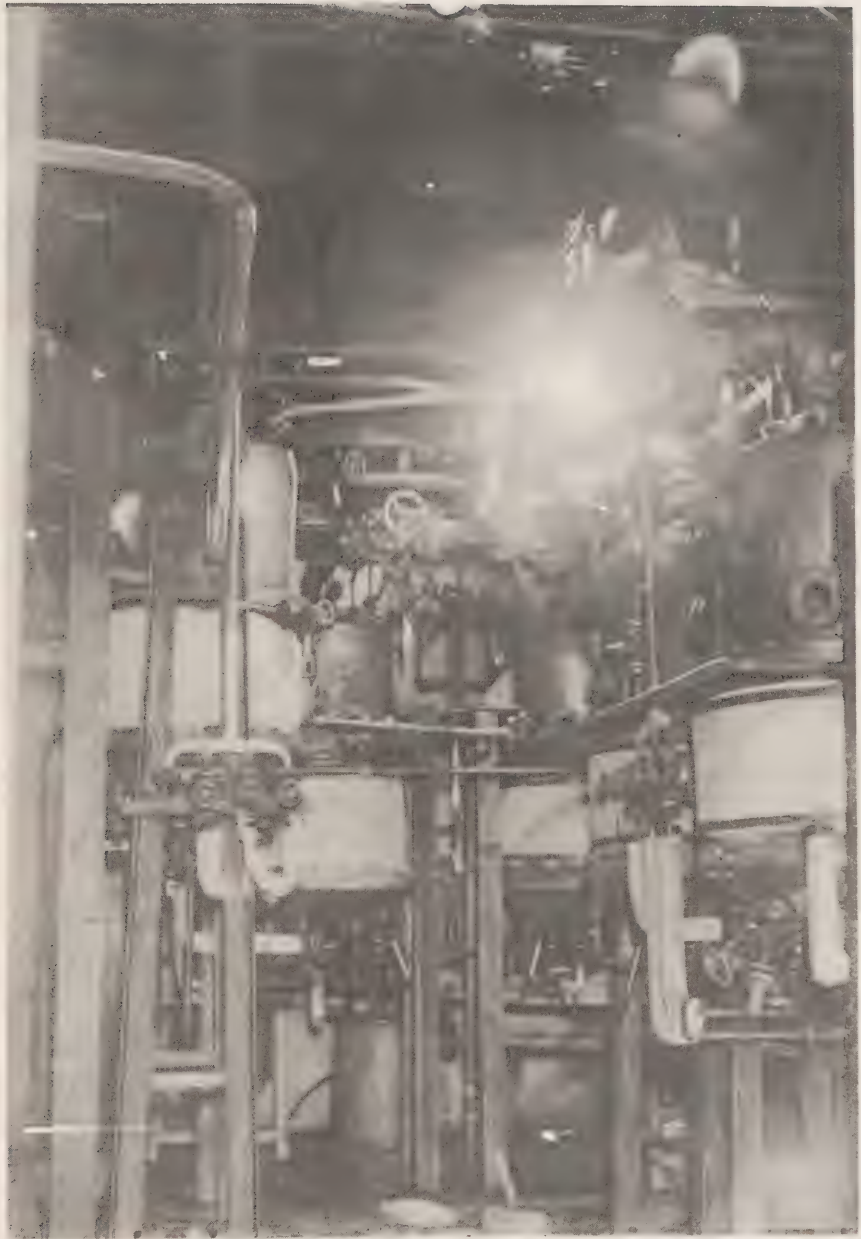
3rd Stage.

250 l/hr. of the B.2/B.3 mixture are drawn into a homogeneously lead lined vaporiser of special design having relatively little liquid capacity and relatively large heating surface (steam heating). Short times of heating are desirable in order to avoid formation of high boiling compounds. 3 vacuum pumps (one working and 2 spare) serve this stage exclusively. The temperature in the 1st boiler is about 70°C. (50 mm Hg pressure at the condenser outlet). Most of the B.2 and some B.3 is vaporised in the 1st boiler. The vapour passes to a bubble plate column (6 plates) then to a partial condenser cooled with water at 17°C and then to a final condenser cooled with water at 3°C. The product from the final condenser is collected in a weighed receiver and then passes to storage. This product contains more than 97 per cent B.2 and constitutes about 70 per cent of the B.2/B.3 mixture. The stripped B.3 from the 1st vaporiser passes to one of two similar vaporisers and the whole of the B.3 is vaporised, passing to a small bubble plate column followed by a partial condenser. The vapour leaving the condenser passes to the 1st bubble tower. Liquid B.3 from the base of the second bubble tower passes to one of two heaters of the same design as the boilers where the temperature is kept at 95°C, (pressure probably 70-80 mm Hg). Residue is withdrawn intermittently from one or other of the B.3 boilers, B.3 is drawn intermittently from one or other of the B.3 heaters. The product contains at least 95 per cent B.3. Residue comprises only 1-2 per cent of the original mixture and contains 30 per cent B.3.

The whole of this distillation equipment was designed by a firm called Avenarius, Berlin.

The pure lead component parts of the plant are fairly resistant to corrosion but the Regulus metal parts e.g. bubble caps and valves have been severely corroded.

HCl evolved during the distillation is absorbed in normal type towers (stoneware lined). The residue is destroyed by caustic soda in a stirred stoneware lined vessel.



Sarin Plant.
B2/B3 Distillation Unit. Steam heated
Boilers. Ground Floor.

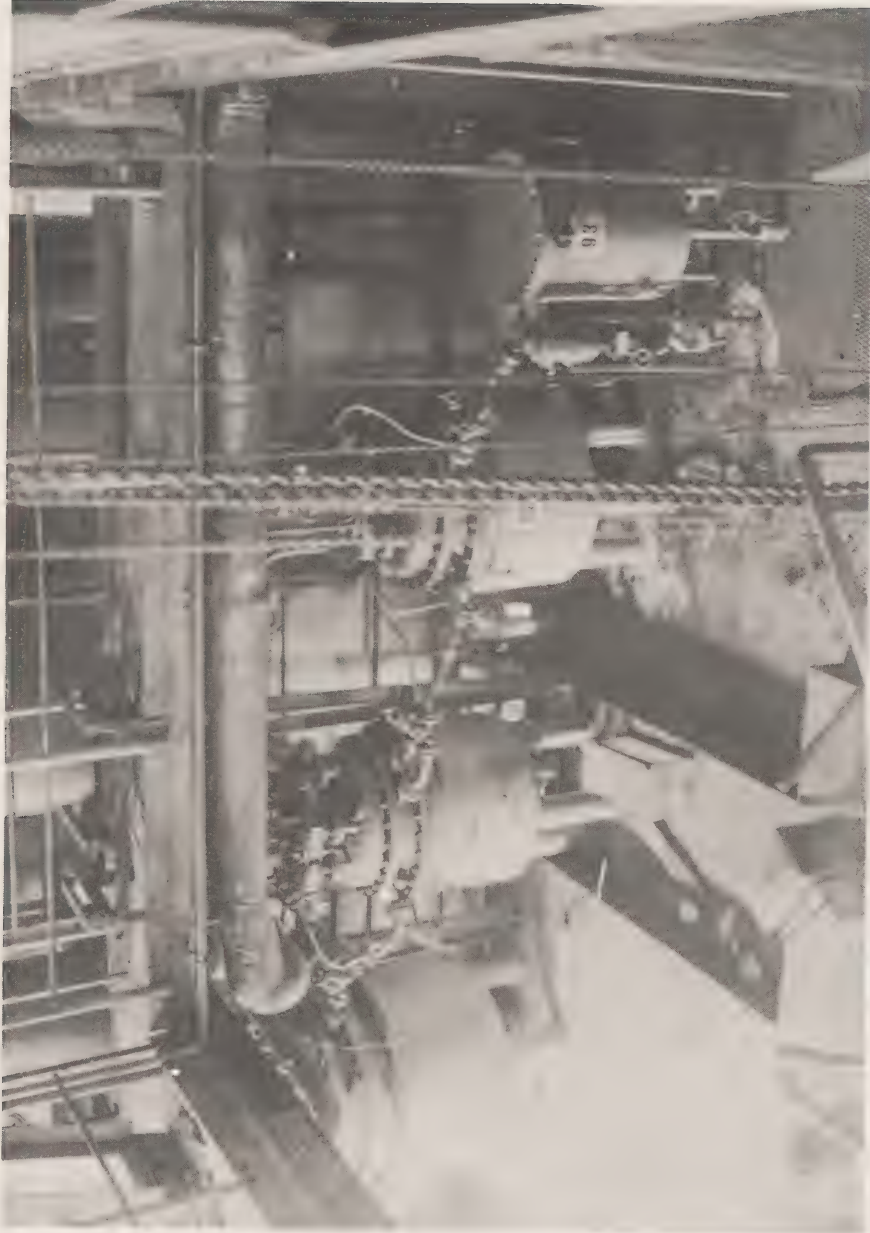


Sarin Plant.
B2/B3 Distillation Unit - Bubble Plate Columns
Commanding the B2 Vapouriser (2nd Floor).



Sarin Plant.

B2/B3 Distillation Unit. Bubble Plate Columns
Commanding the B2 Vapouriser (2nd Floor) and Reflux
Condensers Commanding the Bubble Plate Columns (3rd Floor)



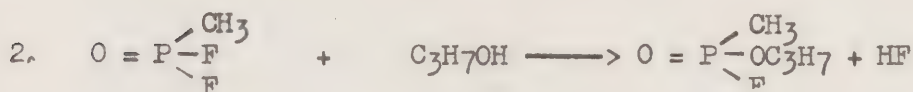
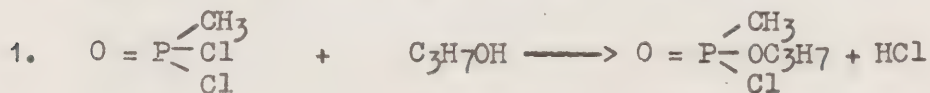
Sarin Plant.
Reactors and Cooler for B4 Preparation. 1st Floor.



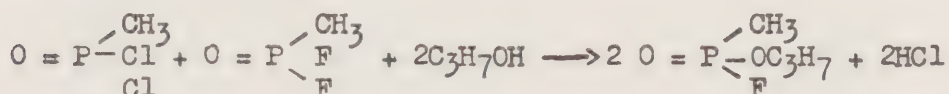
Sarin Plant.
Preparation of B.4 reactors on
1st Floor, Reflux Condensers on 2nd Floor.

5th Stage.

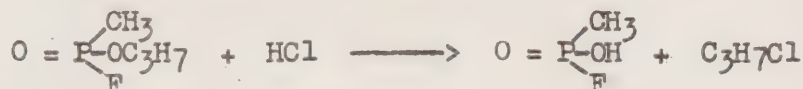
The success of this stage depends upon carrying out the reaction as quickly as possible and in removing HCl as quickly as possible. Silver or carbon surfaces are used throughout. The following series of reactions occur:-



i.e. overall



Unless HCl is rapidly removed from the system, however, the following also occurs:-



B.4 at 80 l/hr and A.2 at 72 l/hr are fed simultaneously into a stirred silver mixer having an internal cooling coil (brine cooling). The temperature is kept below 50°C and the mixture flows into a horizontal silver jacketed tube where the temperature is maintained at 40°C by heating or cooling as necessary (as mentioned earlier this section has only been operated for a few hours). The total reaction time is 15-20 mins. only. The reaction product (pale yellow in colour) is immediately fed to the top of a stripping tower

(two towers are available, one silver lined and one carbon lined). Each tower is in two sections, each about 80 cm dia. and about 5 metres in length. Steam heating sections are spaced at intervals down each tower. Each stripping tower is surmounted by a silver brine cooled reflux condenser and the exit HCl is scrubbed out before the gases reach the vacuum pump. Each tower is packed with Raschig rings.



Sarin Plant.

Preparation of E from B.4. Plant completely enclosed in cubicles. 1st Floor and Ground Floor.



Sarin Plant.
Preparation of E From B.4. Plant Completely
enclosed in cubicles. 2nd and 3rd Floors.

The HCl contains a small amount (5 per cent or so) of HF. The stripping section is operated at 50 mm Hg at the top and 30 mm Hg at the bottom and the stripped E is collected in one of two silver lined receivers. Temperature at column top = 20°C and at column base = 70-75°C. The reaction product contains about 15 per cent HCl, a small per cent A.2 and 66 per cent E, the balance being residue. The stripped product contains 86 per cent E and only one or two per cent HCl, the balance being residue mainly. The stripped E is fed at 100 l/hr to a special silver still employing film heating, operated at 30 mm Hg pressure. The required product (>97 per cent E) is condensed in a water cooled silver partial condenser and collected in a silver lined storage vessel. The uncondensed vapour (90 per cent E 10 per cent A.2) is condensed in a silver condenser firstly cooled by water and finally cooled by brine and collected in a silver lined receiver whence it is returned to the stripping section. Temperature at the base of the still is 90°C. (vapour) and 100-110°C. (liquid residue). The liquid residue is stirred with caustic soda in a special vessel before disposal.

The distilled E is treated with NH_3 in a stirred enamelled vessel to neutralise residual acidity then filtered in steel nutschs with porous stoneware filter plates, allowed to settle, refiltered and then passed to final storage in steel tanks. It is hoped by careful attention to the various stages of the E reaction including stripping and distillation that this NH_3 treatment and filtration may be eliminated. For satisfactory keeping properties the acidic hydrogen in distilled E must not exceed 0.2 grs. per kilo. Provided this figure is not exceeded the material can be stored in steel without a stabiliser.

The E reaction section is equipped with vacuum pumps which serve this section exclusively.

Preparation of A.3 and A.4.

Some information on semi-technical work and production work on preparation of these compounds has been obtained but further information is required from the manufacturers (either from I.G. Leverkusen or from results obtained at Dyhernfurth.

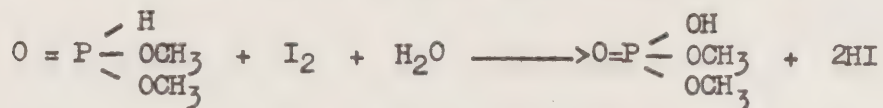
(e) Analytical Methods

Details of methods of analysis of the important intermediates and of the end product are given below:-

A.3. A sample is drawn from bulk storage and tested as follows:

The impurities, chiefly $\text{P} \begin{matrix} \text{(OH)}_2 \\ \text{OCH}_3 \end{matrix}$ are removed by distillation.

The A.3 is treated with N/10 iodine and excess NaHCO_3 .



and the solution is then back titrated with thiosulphate to estimate the iodine used.

(Alternatively, total phosphorus can be estimated by digesting with excess NaOH , acidifying with HNO_3 and estimating P by the molybdate method. This method of analysis is less accurate than the iodine method.)

A.5. Total phosphorus is estimated by digesting with NaOH as above and inorganic phosphorus is estimated by extracting with NaOH , acidifying with HNO_3 and estimating P by the molybdate method. Organic phosphorus is obtained by difference from the figures for total and inorganic phosphorus.

(Note:- It is considered that all the organic P in A.5 is convertible to B.2 and B.3).

B.3. B.3 is separated from B.2 by distillation, the B.2 being distilled off at atmospheric pressure using a good column. A distillate containing over 99 per cent POCl_3 is obtained. The B.3 is then distilled under vacuum and the distillate analysed for total and inorganic P. Total Cl_2 content is measured in the usual manner and the m.pt. is determined. The m.pt. is the most useful criterion for plant control, since it can be determined quickly.

B.4. Total chlorine is measured in the usual manner and dissolved HCl is measured by a calorimetric method utilising the heat of reaction between HCl and acetic anhydride. The organic chlorine can thus be determined by difference. Organic fluorine is more difficult to estimate and is only determined occasionally. Sodium methoxide is reacted with B.4, thereby liberating sodium fluoride from the fluorine-containing constituent of B.4.



The sodium fluoride is estimated by adding alizarin blue in excess HCl and titrating with ZrCl_3 until a colour between blue and yellow is obtained. A standard F solution is then used under similar conditions to obtain a matching colour.

Sarin. Excess N/10 NaOH is added to a weighed sample of Sarin and after 10 minutes the solution is back titrated with N/10 HCl. This gives the NaOH equivalent of Sarin + associated acid

(e.g. $\text{O} = \text{P} \begin{array}{c} \diagup \text{CH}_3 \\ \diagdown \text{OH} \\ \text{F} \end{array}$). Total acidity is then measured by titration

with KI and KIO_3 . The NaOH equivalent of this acid can then be calculated (since any acids present contain one acidic hydrogen only) and the NaOH equivalent of the Sarin obtained by difference. (1 mol. Sarin = 2 mols. NaOH).

(f) Safety Precautions

Rigorous precautions were adopted as regards enclosure of all toxic apparatus in well ventilated cubicles. An antidote known as B-Stoffe was used when operatives appeared likely to die as a result of exposure. This antidote had to be used with great care owing to its highly toxic nature. Decontamination of the plant was effected by caustic soda solution, the operatives wearing oxygen masks during the work. (See also Appendix III - Medical Aspects). A detection method is referred to on page 38.

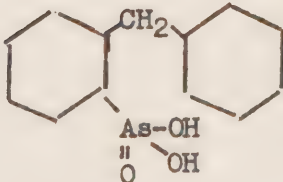
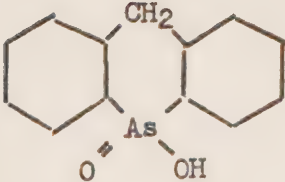
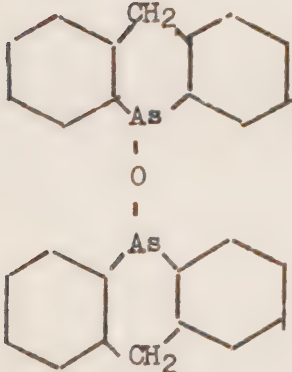
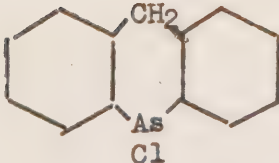
(g) Destruction of Stocks of Sarin

On the approach of the Allied Forces great care was taken to destroy all stocks of Sarin in the plant and in the laboratory and to flush out thoroughly the plant with water. All intermediates, except chlorine were also destroyed or run to waste.

5. Description of the Excelsior Pilot Unit.

The description given below is based on inspection and examination of the plant in and around House C and on information given by Artelt. As in the case of the Sarin process no written records or memoranda have been located. A few drawings have been found including one of the Nutsche filters which may be useful.

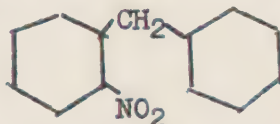
(a) Raw materials and intermediates

<u>Code Letter</u>	<u>Formula</u>	<u>Supplier</u>	<u>M.P.</u>
MERODAN		I.G. (Mainkur)	
IA		Intermediate at R.8 - not isolated.	
IB		Intermediate at R.8	
Excelsior		Final product at R.VIII.	114°C.

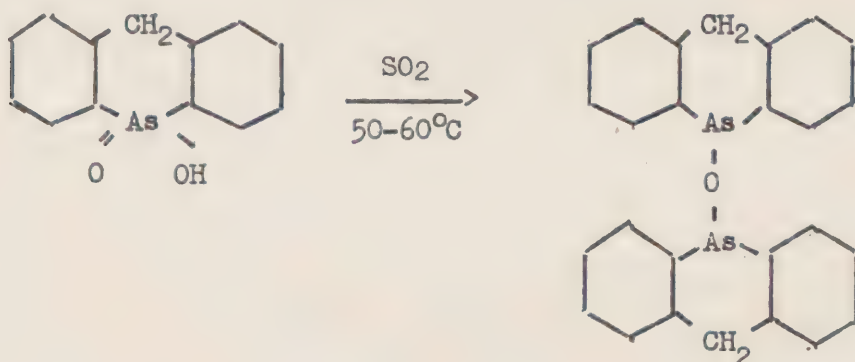
(b) Outline of the Chemistry of the Process

The process by which the whole of the Excelsior so far produced (about 10 tons) has been made in a batch process in which the MERODAN (prepared by I.G. from

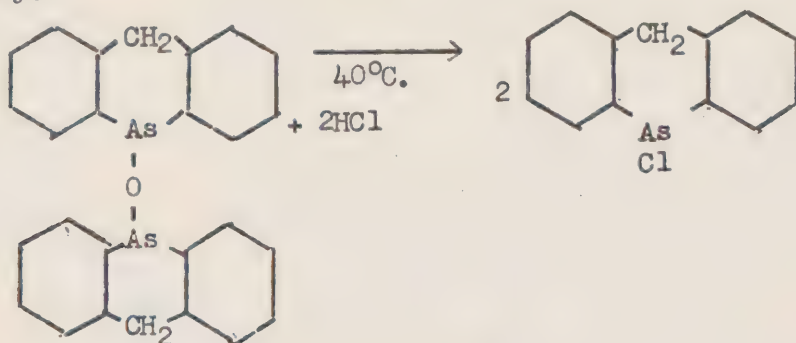
which is



readily available) is first reacted at 95°C with concentrated H₂SO₄ to give product 1A. Concentrated HCl (aqueous) was then added to the reaction mixture and SO₂ gas passed in at 70-75°C. Excelsior was obtained as a finely divided solid after filtration of the reaction mixture. The above process was regarded as unsatisfactory technically owing mainly to severe corrosion problems and a semi-continuous process was developed which was about to be tried on the pilot scale. In this process the first stage using concentrated H₂SO₄ proceeds as before (batchwise) but the reaction mixture is then fed continuously into a tower in which water and SO₂ are continuously introduced. The following reaction takes place:



This product in the form of a suspension in water flows continuously to a stirred reactor into which also concentrated HCl is fed continuously:-



The acid solution is vacuum filtered (nutsches) and the product washed with methyl alcohol and dried by hot air (on the filter).

(c) Plant yields and output

Rated output = 3-4 tons per month. (Artelt estimates that centrifugal filtration would have at least trebled the output). 10 Tons of Excelsior have been produced, entirely by the batch process. The yield on MERODAN was 80 per cent by the batch process and was expected to be at least this by the continuous process. The plant was operated for about 1 year (shortage of supplies of raw material and severe corrosion difficulties interfered considerably with production).

During this period about 10 tons of Excelsior were produced. Difficulties encountered, particularly in the reduction and chlorination stage, resulted also in 15-20 tons of reject material being produced during this period. No Excelsior has been produced during the last 12 months and the stocks of Excelsior and Merodan (except a little Merodan) were sent away from the factory to a storage dump.

It is evident that the performance of the plant using the continuous process is a matter of conjecture. The German C.W. authorities do not appear to have seriously contemplated large scale production of Excelsior.

(d) Details of Plant

The following is a very brief outline of the plant arrangement. The few drawings which are available give details of the important parts of the plant. The description refers to the set up for semi-continuous production.

(i) General arrangement

The reaction vessels are housed in a building known as C House which was formerly used for Tabun production. This building is about 55' long and 35' wide x 30' high. Storage tanks, vacuum pumps and compressors are located, under cover, outside this building. The various plant items are situated on the ground floor and on two stagings. Cooling is effected by a circulating glycerine solution (cooled by an ammonia refrigerating system). Effluent is collected in a small sump and is treated in much the same way as effluent from the Sarin plant (although the two systems are quite separate). Steam at 3 atmospheres pressure is supplied to the building. Air is extracted

from the building as a whole by a main fan. The final product is withdrawn from the filters in a totally enclosed cubicle provided with its own ventilation fan.

(ii) Arrangement of Individual Stages

1st Stage.

400 litres of 99 per cent H_2SO_4 are mixed with 400 kg Merodan in a stirred, steam jacketted enamel lined vessel (1000 litres). H_2SO_4 is fed from a head tank. The reaction takes 30-45 minutes, temperature being 95°C . Two reaction vessels are available but only one is required and the other is used as a feed tank for the filters. This stage has, of course, been fairly well tried out as it was also used in the batch process. Corrosion is not serious and no particular difficulties have been encountered.

2nd Stage.

The acid solution from the 1st stage is pumped at about 60 l/hr. by a small glass pump into the top of a tile lined tower 40 cm i.d. x 2.5 m. high. Spent water from an SO_2 scrubbing tower which takes the effluent SO_2 from the 1st tower is also fed to the top of the 1st tower. The 2nd tower is 0.5 m. diameter and 3.5 m. long and is fabricated in stoneware. The 1st tower is unpacked and is stirred by a vertical shaft having four paddles at intervals (the whole being coated with silver). The 2nd tower is packed with Raschig rings. SO_2 from a vaporiser is fed to the base of the tower 1.4 mols. SO_2 per mol. MERODAN). The water feed at the top of the tower is about 200 l/hr. Temperature in the tower varies from $80-90^\circ\text{C}$. at the top to $40-50^\circ\text{C}$. at the base. SO_2 is obtained from a conventional type of vaporiser and the exhaust SO_2 from the 2nd tower is scrubbed out in a normal type of gas scrubbing system using water as absorbent.

3rd Stage.

The aqueous suspension is fed continuously from the base of the tower to a 2000 litre tile lined stirred vessel

into which 35 per cent HCl is fed continuously (at the rate of 1 mol. pure HCl per mol. MERODAN). It is estimated that the temperature will maintain itself at about 40°C without heating or cooling but if not heating or cooling will need to be introduced.

4th Stage.

The product from the 3rd stage is sucked continuously to a 1000 litre jacketted stirred enamel lined vessel where it is cooled to 10°C. to complete precipitation of the Excelsior. The suspension is transferred intermittently to one of three Nutsches with porous stoneware filter plates. The mother liquor (10-12 per cent H₂SO₄ and 2-3 per cent HCl) is drawn off under vacuum (50-100 mm. Hg) and the precipitate washed with methanol and dried by pulling through warm dry air. The dry material is discharged from the filter by a special mechanism (a drawing of that type of filter is available) and is collected in drums each holding about 80 kg.

Used methanol is collected and dried by fractionation.

The product so obtained is analysed by determination of As content (iodine titration) and can be obtained very pure (98 per cent or better).

(e) Safety precautions

Great care was exercised in avoiding exposure to Excelsior, particularly when discharging material from the filters. Men engaged on this job wore full protective clothing and oxygen masks.

Much thought had been given to possible methods for controlling the purity of the air in a Sarin factory as it was obvious that a serious escape of Sarin into the atmosphere might easily take place without being noticed unless some form of regular test were carried out.

One interesting suggestion had been made, but had not been tried out. This was to make use of a revolving plate with 8 holes which could hold the small silica-gel circles mentioned in Appendix II. When the plate revolved a silica-gel circle would be placed at position (1), then at position (2) air would be sucked through, at (3) hydrogen peroxide added, at (4) tolidine in alcohol added, at (5) ammonia added and at (6) the silica-gel circle examined for colour reactions. If

colour were present an electric bell could be sounded as a warning. The silica-gel circle would be removed at positions (7) and (8). By this means it would be possible to test the air in a Sarin factory for the presence of 0.5 mg/m³ Sarin every half-minute or as often as might be required.

6. Miscellaneous

(a) Information regarding Sarin not yet obtained but believed to be available.

1. Physico-Chemical Data - determined in Sections F.1 and F.3 at Spandau. Information known to Dr. Jung and Dr. Böttger who are not available for interrogation.
2. Design Data. - This information is held primarily by Dr. Gebhardt and partly perhaps by Sneiderwind, neither of whom are available for interrogation. (The importance of obtaining this information is mentioned earlier).
3. Data on Corrosion Rates Corrosion rates were determined by Dr. Doerken of Spandau who was not available for interrogation.

(b) Production Plans for Sarin .

A unit for producing hundred tons/month nearing completion at Dyhernfurth. It was intended at first to use the following process:-

1. $A.4 + PCl_3 + Cl_2 \longrightarrow B.2 + B.3 + CH_3Cl + HCl$
2. Distillation of B.2 + B.3.
3. $B.3 + C_3H_7OH + NaF \longrightarrow E + 2NaCl + NaHF_2$

The last stage is a batch process and is carried out in ethylene dichloride solution. The sodium salts have to be filtered off and the E then separated by distillation from the ethylene dichloride. Being

partly a batch process, the plant required is larger for this process than for the process used at R.8. In addition an A.3-A.5 conversion unit was set up at Dyhernfurth. A larger plant at Falkenhagen was about 25 per cent completed.

(c) Equipment of Special Interest at R.VIII.

Considerable use was made of silver equipment and of a plastic called MIPOLAM (or VINIDUR) which was used extensively for handling mineral acids up to 70°C (but which is not very resistant to organic solvents). A very special type of HCl absorption apparatus, made of carbon, was in use and was capable of producing concentrated HCl in one pass from fresh water and HCl gas, with practically complete absorption of the HCl.

(d) Equipment removed for further examination in England

The following lists the most important items:-

1. Complete silver A.3-A.5 conversion unit.
2. Various silver valves and pipes.
3. Various plastic valves and lines together with welding apparatus.
4. Special stoneware and glass non-return valves.
5. A special high pressure magnetic flow meter for measurement of rate of flow of gaseous HCl.
6. Special insulation material made of cellulose (for low temperature insulation).
7. Various glass lines.
8. A small steel autoclave.

(f) Chemicals removed for examination in England

1. 2 Kegs of Merodan (1 from Burgdorf out of a stock of 40 tons).
2. 1 Kg. of Excelsior (out of a stock of 10 tons found in a salt mine at Burgdorf near Celle).

7. The Manufacture of Tabun at Raubkammer

Some years ago a Pilot plant for the manufacture of Tabun was operated at Raubkammer. The following details, admittedly sketchy, were supplied from memory by a chemist who was associated with the process at the time.

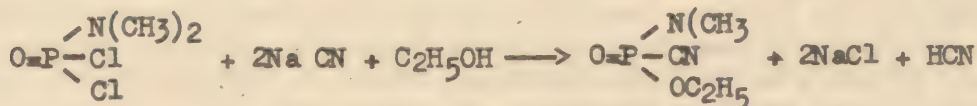
For the preparation of Tabun, POCl_3 is first of all treated with Dimethylamine



This reaction is carried out with cooling on account of its exothermic character. The HCl which is formed reacts at once with an equivalent of dimethylamine to give the hydrochloride. On this account a thick crystalline mass is formed on adding the amine and an excess of POCl_3 is necessary from the beginning in order to be able to stir. The mass is now heated to about 140°C when the amine hydrochloride reacts with the POCl_3 as shown in the above equation with the formation of HCl. The heating is carried out under a well cooled reflux.

After driving off the HCl (which takes one hour in the Laboratory for four gram Mols) the product is fractionally distilled and the dimethylamine compound obtained in 90 per cent yield.

In the second stage the dimethylamine compound is treated with NaCN and ethyl alcohol to form Tabun.



Chlorbenzene is used as solvent and the NaCN is first of all suspended in this by stirring, then about half of the dimethylamine compound added, and the reaction started by adding alcohol. Then the dimethylamine compound and alcohol are added at the same time with cooling so that the temperature is kept at 40°C . Towards the finish the addition of the remaining alcohol can be accomplished fairly quickly. The HCN which is formed is driven off by heating and reaction product filtered off from the sodium chloride. The saltcake is washed with chlorbenzene, and the chlorbenzene is then removed from the filtrate in vacuum.

The brown coloured raw Tabun obtained in this way can be distilled in small quantities in the Laboratory, if great care is taken, to give a water clear liquid. During this process energetic decomposition may take place whereby part of the liquid forms a brown oil. Small quantities of NaCN in the raw Tabun appear to act as catalyst for the decomposition. Tabun which has once been distilled can be redistilled without difficulty. It is not possible to distil Tabun in the technical preparation as the appearance of such decomposition might lead to sudden unexpected rises of temperature which could be catastrophic.

Code Names used on Plant.

POCl_3	=	Oxysäure or Acetylchlorid B
$\text{NH}(\text{CH}_3)_2$	=	Ina or C3-Base
$\text{O}=\text{P} \begin{array}{l} \nearrow \text{N}(\text{CH}_3)_2 \\ \searrow \text{Cl} \\ \text{Cl} \end{array}$	=	Stoff 39.
NaCN	=	Na Salz.

Technical

(a) Preparation of Stoff 39.

The POCl_3 was stored in leaded vessels. The dimethylamine was kept under pressure in an iron container which could be cooled with brine or heated by steam. The cooling was necessary in order to obtain the required fall in pressure when filling the container from tank wagons etc. On the other hand heating was necessary in order to get the required pressure to fill the measuring vessel. The measuring vessel was mounted on a weighing machine. A spiral tube which could be cooled by brine to -10°C was built in between the storage container and the weighable measuring vessel so that the latter could be easily filled at any time without the use of outside pressure.

The reaction vessel consisted of an enamel container (2 m^3) fitted with a stoving apparatus and an enamel reflux condenser. The jacket of the condenser could be cooled with pre-cooled brine (for part I of reaction) and could be heated with pre-heated (electric) oil up to a temperature of about 180°C .

The POCl_3 was pulled over into a lead measuring vessel and thence into the reaction vessel by means of vacuum.

(A brine cooled lead spiral which was built into the reaction vessel did not stand up to requirements and was completely destroyed by corrosion and erosion after four runs.)

The addition of the dimethylamine to the POCl_3 was carried out by means of a control valve cooled by oil and the dimethylamine itself was introduced through a brine cooled spiral at -10°C . The addition was regulated in such a manner as to raise the temperature in the reaction vessel to about 170° at the finish. For each run about 4-5 Kg. Mol. i.e. 180-225 Kg dimethylamine were added.

When all the dimethylamine had been added the cooling oil was let out of the condenser jacket and oil heated up to 180°C pumped in. The HCl formed during the reaction escaped through the reflux condenser to an upright brine cooled condenser and thence into a Raschig ring tower and finally to a HCl absorption apparatus. The POCl_3 which was condensed in the upright condenser and Raschig ring tower was led back into the reaction vessel. The escaping HCl was measured by a Rotameter built in behind the Raschig ring tower. Driving off the HCl , contrary to experience in the Laboratory, took a very long time - 10-11 hours.

As soon as no more HCl was being given off (noticeable by a fall in temperature in the upper part of the reflux condenser which is at 90°C whilst the bulk of the HCl is being given off), the temperature of the reaction vessel having risen to about $130-140^\circ\text{C}$ the heating was turned off and the contents of the reaction vessel cooled to 80°C .

The reaction mixture was now pulled over into a leaded distillation vessel and fractionally distilled in vacuum. As the POCl_3 which separated contained Stoff 39 it was led back with the reaction. To control the distillation continual specific gravity measurements were made.

The yields were very good and always over 90 per cent (sometimes 98 per cent). The viscous mass left in the reaction vessel was sucked out and carefully destroyed with water.

The great difficulty with this process was corrosion. The built in hard lead valves continually leaked and were choked up with lead chloride from the feed pipes. Enamel valves with high grade steel which were tried out proved good.

All the enamel parts behaved in general well.

(b) Preparation of Tabun.

Chlorbenzol was introduced into an enamel vessel (2 m³) and NaCN added by hand through a filling funnel. Stoff 39 and alcohol were then added as described above. The filters used were the same as those now used for Excelsior. The bottle neck in the manufacture was the filtration as the NaCl often separated in a slimy form which was difficult to filter and, therefore, took a long time.

The HCN which was formed was burned on the top of the roof.

As an excess of NaCN had to be used the salt cake which was filtered off contained some unattacked NaCN. In order to prevent contamination of the effluent with NaCN the dissolved salt was treated in an enamel vessel with HCl and the solution heated to get rid of the HCl. The HCN which was given off was burned.

There were no corrosion difficulties with this part of the process.

The yield was about 80 per cent.

8. C.W. Production in Germany

Information obtained by the interrogation of an authoritative member of Prüf 9 is given in Table I. It should be noted that Prüf 9 were not responsible in any way for production and therefore the table may not be complete or entirely accurate.

TABLE I.

No.	Place	Company	Material Made	Capacity (tons/month)
1.	Ammendorf	Orgacid	Thiodiglycol H. $\frac{1}{3}$ could be turned over to make HT. The plant could also make OM. Nitrogen mustard (Triethanolamine from Ludwigshafen.)	450
2.	Huls.	I.G.	Thiodiglycol H. Special continuous process. Could also be used for HT or OM, also had a small sulphur dichloride plant, possibly now dismantled.	100
3.	Gendorf (Hochwerke)	Anorgana G.n.b.H. Montan Ges.	H by sulphur dichloride process.	4,000 projected, 1,000 completed.
4.	Stassfurt	Ergethan G.n.b.H.	Arsinöl.	180
5.	Leese	Lonal	Arsinöl.	450
6.	Leese	Riedel de Haen.	Chloroacetophenone.	600
7.	Seelze Nr.Hanover.	Riedel de Haen.	Chloroacetophenone.	120
8.	Haselhorst Nr.Berlin.	Lonal.	Clark I and II. Worked out continuous process for diphosgene but no plant supplied. Trying technical manufacture of phosgene oxime.	80

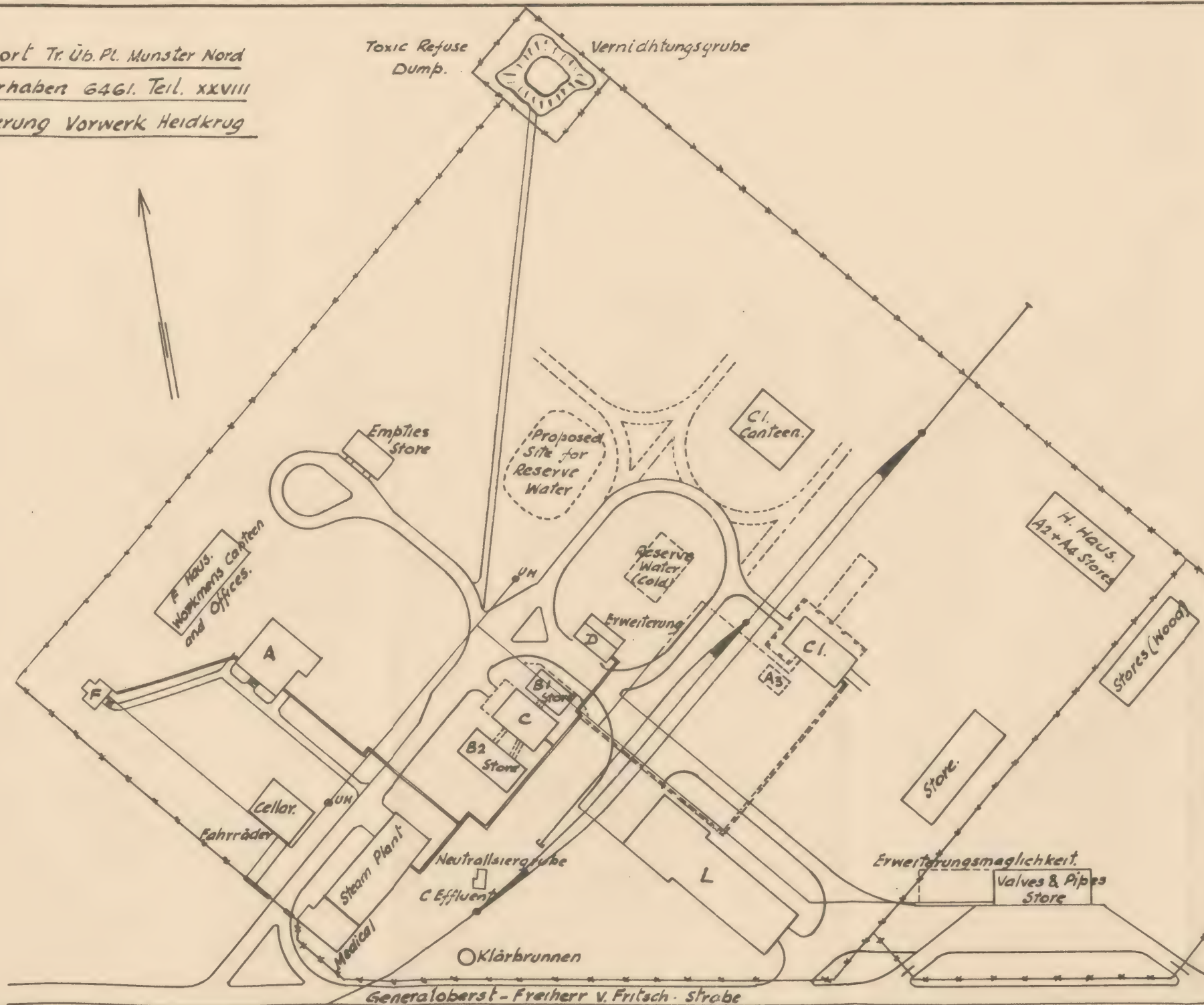
TABLE I (Continued)

No.	Place	Company.	Material Made.	Capacity (tons/month)
9.	Dyhernfurth (Niederwerke)	Anorgana G.n.b.H. Montan Ges.	Tabun Sarin Cyanogen chloride Big plant for Aeroform planned, but not supplied.	1,000 100 ($\frac{3}{4}$ completed) 100 (nearly completed)
10.	Falkenhagen (Seewarke)	Monturon Ges.	Sarin.	500 ($\frac{1}{4}$ completed).
11.	Mainkur Nr. Frankfurt	I.G.	Merodansaur	
12.	Raubkammer (Heidkrug)		Sarin. Excelsior.	50 ($\frac{1}{2}$ ton made) 3 to 4.
13.	Urdingen.	I.G.	D.M.	400 Never made more than 200.
14.	Ludwigshafen	I.G.	Phosgene	Variable wanted 800 to 1,000.
15.	Wolfen.	I.G.	Phosgene	
16.	Bitterfeld.	I.G.	Had small pilot plant for Aeroform.	

9. Conversion of mustard gas to commercial products.

The Germans had given very little consideration to the possibility of converting mustard gas into products having commercial uses. The French had worked on a process in which mustard is oxidised with nitric acid the resulting chloroethylsulphonic acid converted to Taurine. This proved to be an expensive process using a large quantity of nitric acid and giving a poor yield. A Russian deserter suggested the condensation of mustard with sodium sulphide to give a resin suitable for the manufacture of gramophone records. This was investigated at some length, but no success was achieved. Apart from the above, there appeared to have been little investigation into this matter.

Standort Tr. Üb. Pl. Munster Nord
Bauvorhaben 6461. Teil. xxviii
Erweiterung Vorwerk Heidkrug



DISPOSITION OF BUILDINGS

IN R 8.

RAUBKANMER BEI MUNSTER

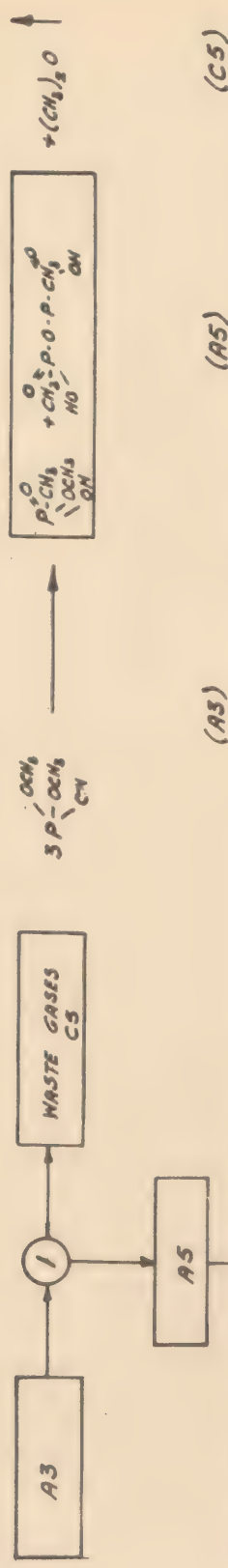
MAY 1945

FIG. I.

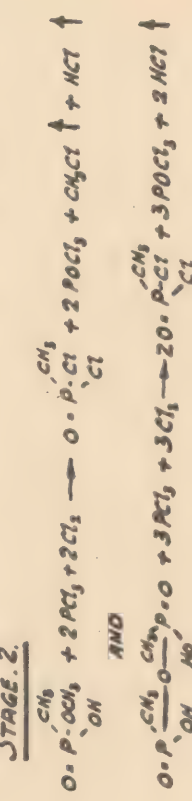
FLOW SHEET FOR MANUFACTURE OF 'SARIN'

FIG. II.

STAGE 1.

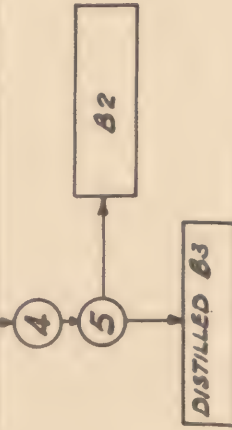


STAGE 2.

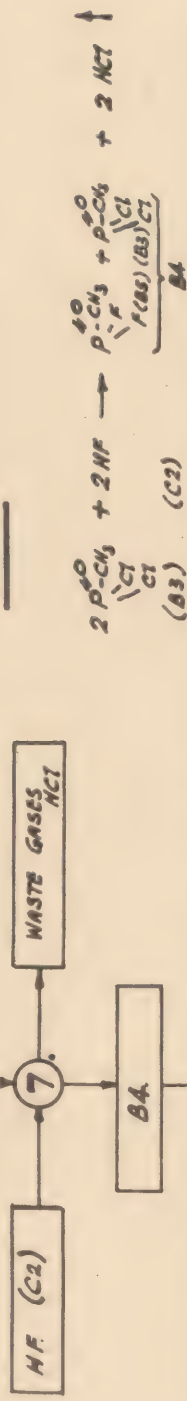


STAGE 3.

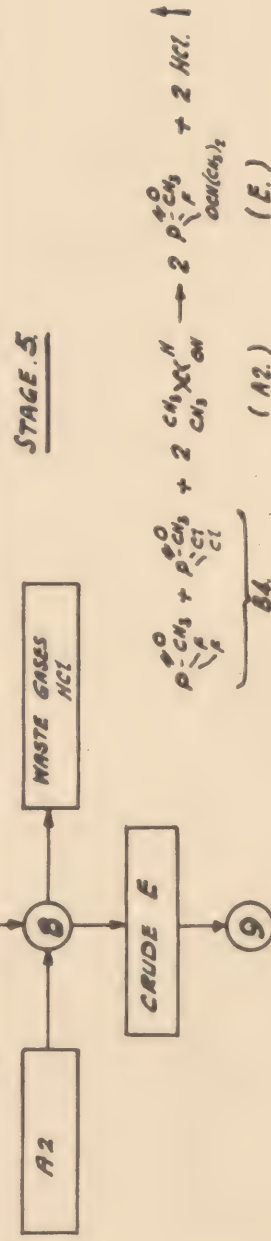
SEPARATION OF B2 AND B3 BY FRACTIONAL DISTILLATION AT REDUCED PRESSURE.



STAGE 4.

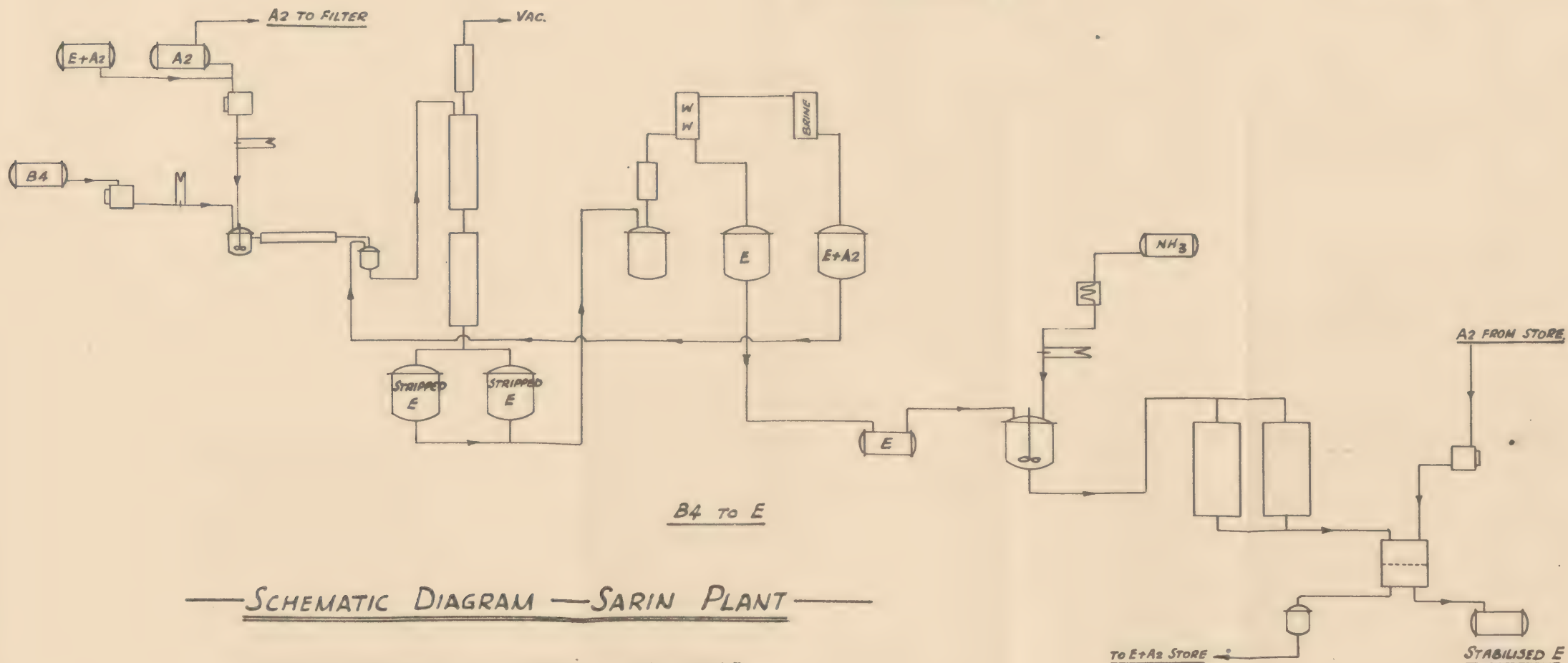
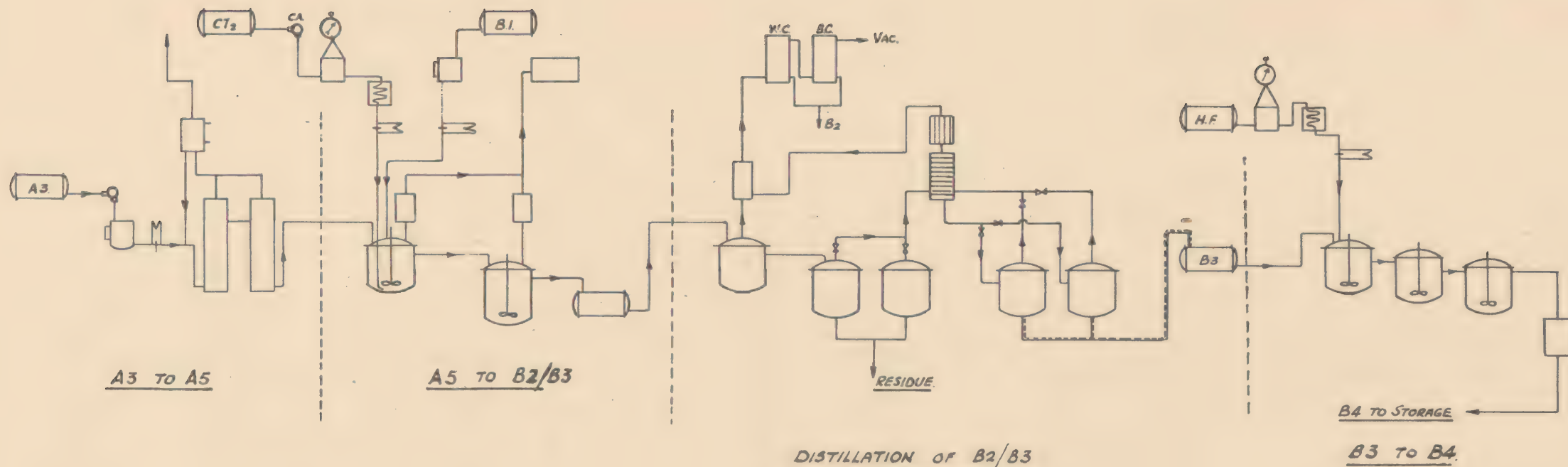


STAGE 5.



KEY.

- | | |
|--------------------|-----------------------|
| 1. A3-A5 CONVERTER | 8. E CONVERTER |
| 2. CHLORINATOR | 9. DEGASSER |
| 3. DEGASSER | 10. STILL |
| 4. CRUDE B3 STORE | 11. DISTILLED E STORE |
| 5. B3 STILL | 12. NEUTRALIZER |
| 6. B3 STORE | 13. FILTER |
| 7. FLUORINATOR | 14. PRODUCT STORE |



SCHEMATIC DIAGRAM — SARIN PLANT —

RAUBKAMMER BEI MUNSTER

MAY 1945

FIG. III.



— DIAGRAMMATIC LAY-OUT — SARIN PLANT. —

RAUBKAMMER BEI MUNSTER

MAY 1945

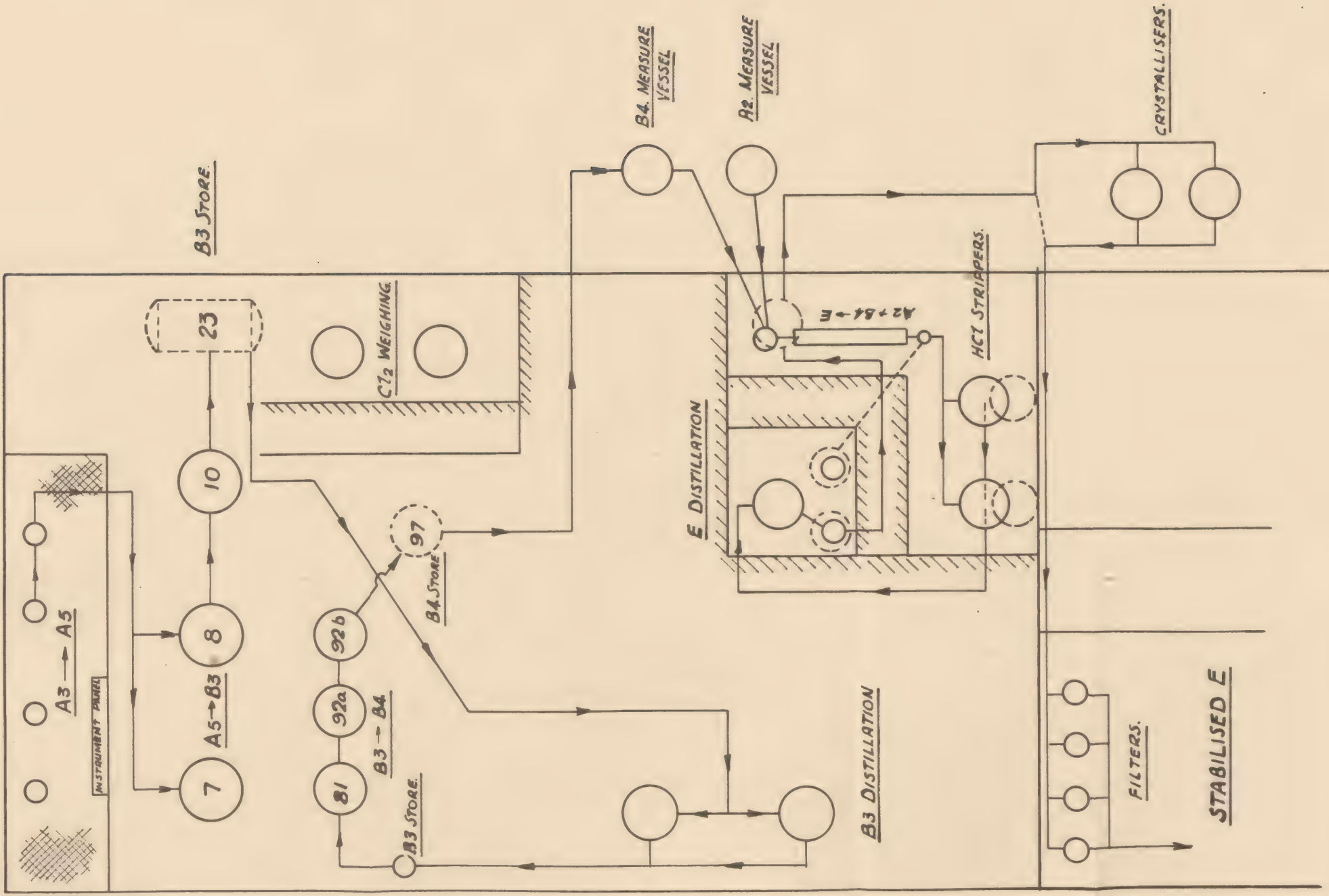


FIG. IV.

Investigation of Chemical Warfare Installations
in the Munsterlager Area, including Raubkammer

APPENDIX VI

RESEARCH

German chemical warfare research work might be roughly subdivided into three separate channels :-

- (a) the work done in the research laboratories at Spandau.
- (b) the work requested by Wa. Prüf. 9 from the various Academical Institutions.
- (c) the work carried out by the industrial firms themselves.

Little will be said here with regard to (c) as although theoretically all research and development work was guided by Wa Prüf 9 they had in fact little control over the research work of the various industrial firms and merely used the results of their research work as it became useful. The research work of industrial firms will therefore be left to the reports of those who have visited the actual firms.

In Spandau in addition to the Laboratories for development work, there were also five research institutes (Forschungs Institute) called F1 to F5. Each of these research institutes was under the direction of its own head who was entirely responsible for the work carried out and reported only to the head of Wa Prüf 9, Oberst Hirsch. There had evidently formerly been some sort of a Committee to discuss the work to be done by the research institutes, but this Committee had now ceased to function and the work was directed entirely by Oberst Hirsch, although a certain amount of the co-ordination of the work fell to the head of Group V, Professor Wagner. At least one director of a research institute appears to have been well satisfied when this Committee ceased to exist and the constant demand for all sorts of wierd compounds which might possibly be of some interest came to an end.

The head of Group V, Professor Wagner, was expected to co-ordinate all research work, see that there was no overlapping and that the work was being done as far as possible by the most suitable team, but presumably he only advised Oberst Hirsch on possible action to be taken and had himself no direct control of research.

The research institutes at Spandau were :-

F1 - Chemical Institute	Director:- Dr. Reetz
F2 - Analytical Institute	Dr. K��lliker
F3 - Physical and Physico- Chemical Institute	Prof. Jung
F4 - Research Laboratory for Group I	Dr. Zeumer
F5 - Library	Dr. Metzener

Research Institute F1

Director :- Dr. Reetz
 Assistant Director :- Dr. B  ttger

Other interrogated :- Herr Zahn.

In addition to the Director and Assistant Director there were 6 chemists, 16 Laboratory assistants, 2 typists and 4 workmen employed in F1.

The chief fields of work were :-

- (1) Synthesis of new war gases
- (2) Scientific investigation of chemico-technical problems.
- (3) Discovery of new reactions for the preparation of new compounds as well as for known war gases.
- (4) Examination of captured war gases (but never had any).
- (5) With F2 the preparation of compounds required for analysis.
- (6) With F3 the preparation of pure substances for the measurement of physical properties.
- (7) With VII and VIIL the testing of new compounds and discussions on new compounds which might be prepared.
- (8) With VIII and VIIL the introduction of new methods of preparation and analysis discovered by F1.

Preparation of Sarin and Soman

The main work of the F1 institute had been concentrated during the past few years on a study of the methods of preparation of Sarin and Soman, and many notable improvements in the methods of preparation had been developed. After a long and careful study an apparatus had been devised and set up in the laboratory which was capable of producing an appreciable amount of Sarin (half to 2 tons a month) and which could be used for the preparation of Soman. This apparatus is described in the following five steps, but it should be remembered that the details have all been supplied entirely from memory.

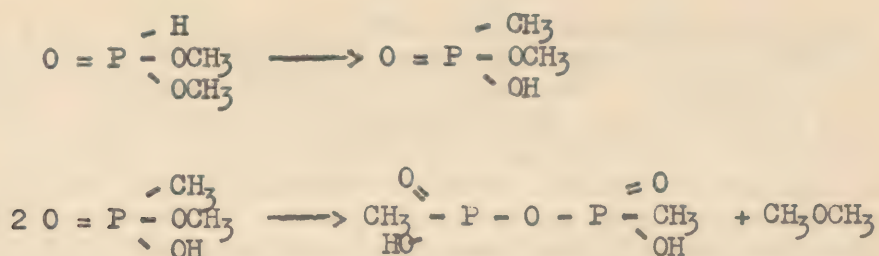
Step I (Fig.I)



Carefully measured quantities of PCl_3 and CH_3OH were allowed to drop through fine openings in a tube on to a drum revolving inside a reaction vessel and kept cool by means of an internal stream of tap-water. It was found that the PCl_3 should not be in excess and that more than 10 per cent excess of CH_3OH was also inadvisable due to the solubility of HCl in CH_3OH . It was found best to work with about a five per cent excess of CH_3OH . It was thought that the revolving drum would best be made of silver strengthened on the inside with steel, but such a drum had not yet been tried out at Spandau. A copper drum was used, but this was soon attacked and it was intended to replace this with a silver one.

The product of the reaction passed through a vacuum trap to an evaporation column kept warm with water at 60°C where most of the volatile by-products were removed and the crude product was then collected below. It was found to be an improvement to employ more than one column to remove the volatile matter and if possible to remove these so effectively that the raw product did not contain more than 2 per cent of HCl .

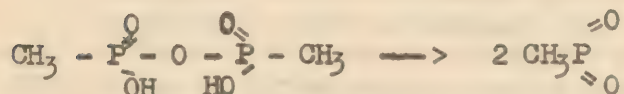
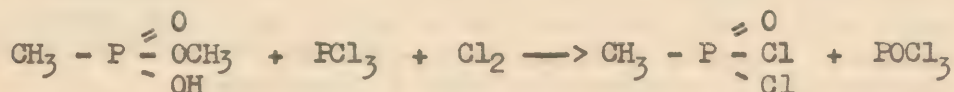
Step II (Fig. II)



The product from Step I was passed through a measuring pump and led into the bottom of a vessel containing Step II product at 280°C . Rearrangement took place and the liquid overflowed into another exactly similar vessel where the reaction was supposed to be completed. It was not considered that this second vessel was really necessary, but it was found to be quite convenient. Both these vessels were kept under an atmosphere of nitrogen and the stream of entering nitrogen was regulated in such a manner that the glow of the escaping gases burning in the escape tube from the first vessel was never allowed to approach near the actual reaction vessel. The escaping gases were chiefly CH_3OCH_3 , PH_3 , P_2H_4 and CH_4 . All this apparatus was made of quartz. This reaction was discovered by F1, but some care had to be taken to regulate temperatures etc. when carrying it out in the laboratory as the reaction could proceed explosively especially if the temperature was too high or too large quantities of the dimethyl ester were being rearranged in the reaction vessel at one time.

In Fig. II the product of the rearrangement is shown as being collected in a separate vessel, but actually it was found to be best to lead this product direct on to Step III as even at 110°C it was rather viscous and it was much easier to measure in the correct quantities for Step II.

Step III (Fig. III)



The rearranged product from Step II was led hot via a heated quartz funnel into a reaction vessel into which PCl_3 and chlorine were carefully measured. The temperature of the reaction vessel was kept to about 60°C. by means of an internal coil circulating cold water. From the bottom of the vessel the product was led away over a syphon, which, was used to control the time of chlorination, to the receiving vessel, where the dichloride and phosphorus oxychloride were collected for distillation. It was considered most important to see that the correct amounts of chlorine and PCl_3 were added. An excess of chlorine was shown by a yellow colour due to the formation of PCl_5 whilst a white turbulence indicated that too little chlorine had been added.

Impurities obtained during the purification of the dichloride have been collected and examined. They were found to consist of :-

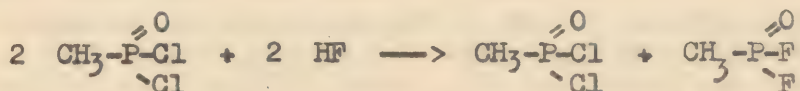
- (a) phosphorus oxychloride due to insufficient fractionation
- (b) $\text{CH}_3 - \text{P} \begin{array}{c} \text{O} \\ \parallel \\ \text{OCH}_3 \\ \text{Cl} \end{array}$ due to insufficient chlorination of the dimethyl ester
- (c) CH_3PO_2 probably due to decomposition of the ester chloride.
- (d) $\text{CCl}_3 - \text{P} \begin{array}{c} \text{O} \\ \parallel \\ \text{Cl} \end{array}$ due to excessive chlorination of the dimethyl ester
- (e) CCl_4 in traces due to excessive chlorination.

All these impurities were only found in very small quantities.

$\text{CCl}_3\text{POCl}_2$ was found to be a white waxy solid which sublimed. In water and cold NaOH it split off only one chlorine atom, but in hot NaOH all five were split off.

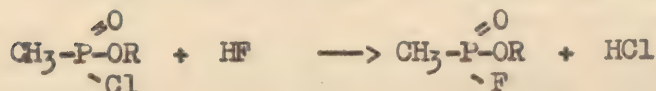
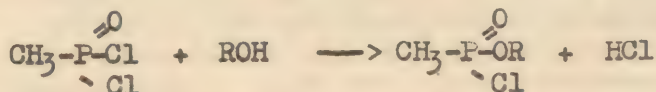
The distillation of the product from Step III was effectively carried out in the apparatus shown in Fig. VI.

Step IV (Fig. IV)



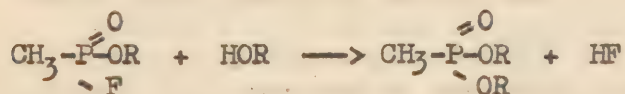
The dichloride from Step III was placed in a long glass vessel (one third full - 3 litres) and H_2F_2 was led in from a cylinder placed on a weighing machine and connected by means of a copper spiral to a copper tube which dipped down to the bottom of the vessel. The temperature of the reaction vessel was kept at about 85°C . and the HCl escaped through a condenser. Except for the copper dip-pipe it was found that the whole of the apparatus could be made of glass.

Step V (Fig. V)



The product from Step IV and isopropyl alcohol were carefully measured into a 200 ml mixing vessel which was kept cool by means of an internal coil circulating cold water. The contents were mixed by passing in nitrogen through a tube dipping down to the bottom of the vessel. The addition was so arranged that the reactants remained in the mixing vessel about 5 minutes when they passed through an overflow pipe into a long reaction tube placed at a very slight angle so that the contents tended to move towards the far end. The tube was kept at about 40°C by means of an internal circulation of hot water. HCl escaped from the mixing vessel and reaction vessel through a single condenser. A tube leading out of the far end of the reaction vessel had a tap so adjusted that the reagents remained in the reaction vessel for 15 to 16 minutes.

On leaving the reaction vessel the product contained about 12 per cent HCl and it was important that this should be removed as quickly as possible without subjecting the product to the presence of appreciable quantities of HCl at a temperature where saponification of the ester might take place readily. The HCl was therefore removed in three stages as shown in the sketch so that the HCl removed in the latter stages did not affect the previous stages and the temperature could be raised gradually. Good cooling for the condenser was necessary and brine at -15°C was used. It was also found that silver condensers conducted the heat better. The product still contained 2 per cent HCl and it was important that it did not contain free alcohol otherwise HF was formed and this caused difficulties in the distillation.



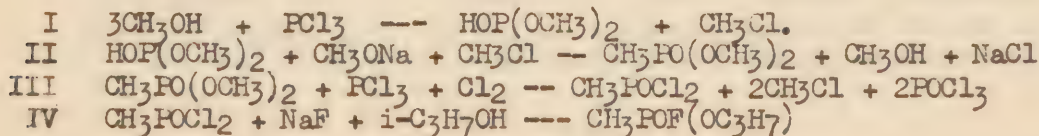
A method for estimating small quantities of alcohol was said to have been worked out by Dr. Bottger (F1).

The product was now distilled in the same apparatus for continuous distillation as was shown above and provided there was no large percentage of impurities present there was no difficulty with the distillation and a pure product was obtained in good yield. Sometimes if the reaction had not gone well it was necessary to treat with ammonia and filter before distillation, but this was avoided if possible.

All workers laid great stress on the care which was necessary when working with Sarin and that all pumps should be guarded with NaOH.

One great advantage of the above methods and apparatus was that a similar technique could be used for the preparation of Soman. It was only necessary to make slight alterations in the method of carrying out Step V. Here pinacolyl alcohol was used in place of isopropyl alcohol. The reactants were kept in the mixing vessel for 8 minutes and warmed slightly when they passed on into the reaction tube where they remained for about 40 minutes at a temperature of 60°C .

The above method was found to be most useful for the preparation of Sarin in larger quantities. Previously other methods had been used such as



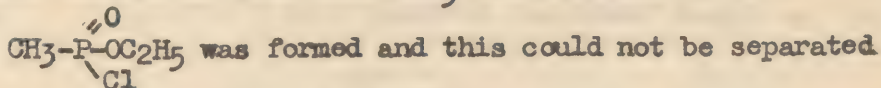
I could be carried out with or without solvent, but required good stirring. It was best to add the reactants at -10°C . then gradually allow the temperature to rise in the same flask and to pull off the HCl until only 2 per cent was left.

II All the reagents were added separately with a trace of iodine in the CH_3Cl . Kept at 40°C . then the NaCl filtered off and the product distilled.

III Ester, PCl_3 and chlorine were introduced into the reaction vessel at a low temperature. Sometimes POCl_3 was tried as a solvent but no one was sure that it had produced any improvement in yield. When all the reagents had been added gradually the temperature was raised, the solvents distilled off and the product distilled in vacuum.

IV Sodium fluoride was suspended in benzene, trichlorethylene, carbon tetrachloride or chlorbenzol plus one half per cent of water and isopropyl alcohol. The dichloride dissolved in the same solvent was added at $60-70^{\circ}\text{C}$. (1 mol. dichloride in 50 ml. solvent added to 150 g. NaF. in 160 ml. solvent and 1 mol Isopropyl alcohol. After filtration and distillation of the solvent the product was distilled. Great care had to be taken that there was no big excess of acid otherwise there was a very big decomposition of the product on distillation.

It was also possible to make the diethyl ester as in the first stage of either of the above methods, but a change was then necessary in the method of chlorination. The diethyl ester had to be treated first with HCl at 150°C . to obtain the free acid which could be isolated and crystallised from petroleum ether if desired. As a rule, however, no purification was carried out and the crude acid was treated with an equivalent quantity of PCl_3 and chlorine. If the diethyl ester was treated at once with PCl_3 and chlorine or with PCl_5 then some



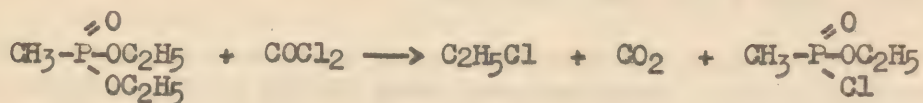
from the dichloride by distillation.

IV above was also carried out using the following alcohols in place of isopropyl alcohol

methyl alcohol	at 60°C .
ethyl	60
n-propyl	60
sec-butyl	75
sec-amyl	80
cycle-hexanol	70
pinacolyl	over 100

The yield in each case was of the order of 60 to 85 per cent.

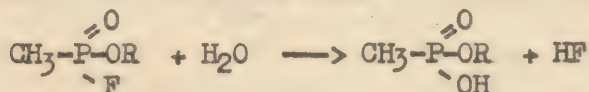
A new method had also been worked out for the preparation of ethyl-Sarin by allowing phosgene to react on diethyl methyl phosphonate at room temperature or up to 30 to 40°C.



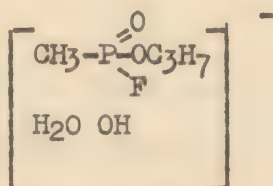
The ethyl methylphosphoryl chloride so obtained could be distilled and allowed to react with sodium fluoride to give fluoro-ethoxy-methyl-phosphine oxide in 80 to 85 per cent yield. Unfortunately this method of preparation could not be adapted so well for the preparation of Sarin as phosgene did not appear to react so well with the di-isopropyl ester, but the possibilities of this method were still being most carefully examined in F1.

A large number of other compounds of the Sarin series $\text{R}-\overset{\overset{\text{O}}{\parallel}}{\underset{\underset{\text{F}}{|}}{\text{P}}}-\text{OR}'$ were prepared. It was found that the compounds became less effective as R' increased in molecular weight CH_3 , C_2H_5 , C_3H_7 etc. Nearly all compounds where R' was a secondary alcohol were good and much better than the compounds derived from the corresponding primary alcohols. Any substitution of a methyl group for a hydrogen in the group R' seemed to increase the activity of the compound. Professor Huckel of the University of Breslau was said to be very interested in these fluorine compounds and in the relationship between the constitution and physiological activity. Further information on the relative effectiveness of members of this series is given in Appendix III.

It was also proposed to study the rates of hydrolysis of the esters of the Sarin series and to try to correlate this with the toxicological effect. A study of the action of water on Sarin appeared to have raised problems which had by no means been cleared up. Physical research in department F3 seemed to show that there was an almost immediate decomposition of Sarin.



but toxicological measurements by Dr. Sextl were said to have shown that Sarin retained its toxicological activity in water for at least 60 hours. F1 considered that there might be the immediate formation of a complex in water such as



and that this complex could then react with a ferment, the ferment replacing the molecule of water in the complex. Obviously more knowledge of the work done by the physical chemists of F3 on this problem is required.

The action of heat on Sarin was studied and it was found that Sarin when heated at its boiling point (154°C) for 4 to 5 hours

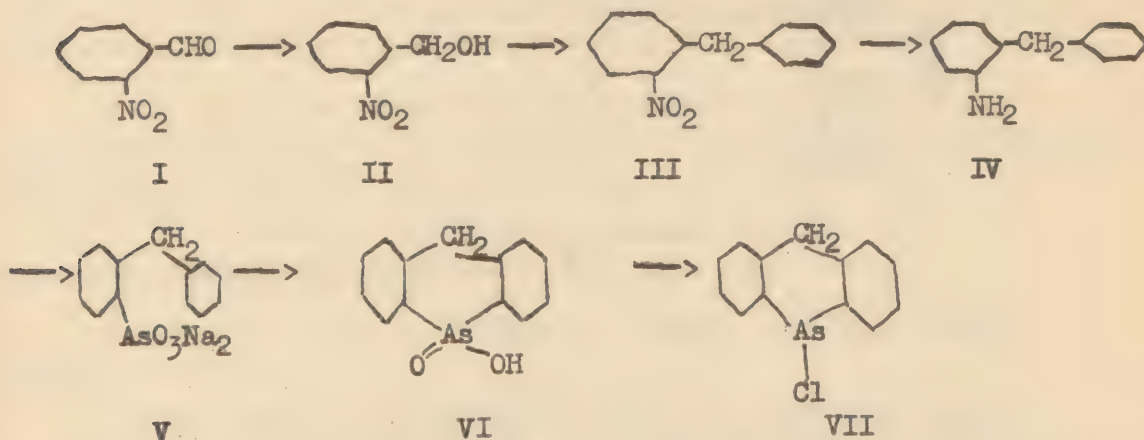
decomposed into $\text{CH}_3\text{-P}(=\text{O})(\text{OH})\text{F}$ and propylene. The decomposition

started very slowly, but it was auto-catalytic and became finally violent. The speed of the decomposition was increased by the presence of hydrogen ions and therefore the acid decomposition product increased the rate of decomposition. If iron filings or amines were added to the Sarin the speed of decomposition was very much slower.

Various trials of the stability of Sarin at 20° and 60°C. were carried out. It was found that glass caused decomposition and that silver was unable to combine with the acid decomposition product and prevent an eventual rapid decomposition. Sarin was most stable in iron containers where one year at 20°C. produced 2 to 4 per cent decomposition and one year at 60°C. produced 10 to 15 percent decomposition. Sarin stored in iron vessels is colourless, but on opening to the air it becomes blue and then brown due to the presence of complex iron salts. Sarin containing acid did not keep at all well.

Preparation of Excelsior

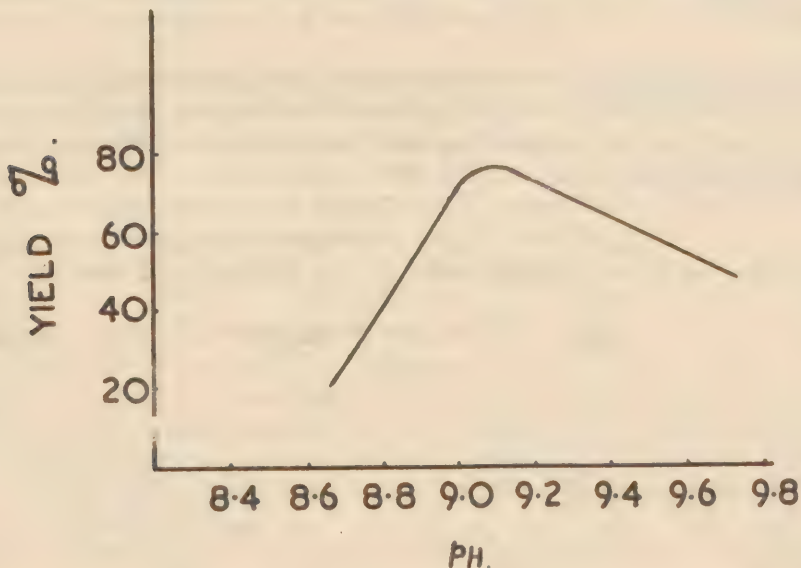
The preparation of Excelsior had also been studied. The reactions involved were :-



o-Amino-diphenyl was produced by the I.G. according to a published patent.

The Barth reaction for the preparation of V from IV has been studied at Spandau. Gump and Stolzenberg, J. Amer. Chem. Soc., described the yield of V as poor, but Steinkopf and others were able to show that by alteration of the reaction conditions the yield could be increased to about 60 per cent. Sometimes yields of up to 70 per cent were obtained without it being quite understood which altered conditions had achieved this increase in yield and it was decided to study the reaction in F1.

The diazonium chloride of IV did not react at all with sodium arsenite in acid solution and in caustic soda solution the yields were very poor. The use of carbonate increased the yield. It was obvious that a study of the effect of pH on the reaction was necessary keeping such other factors as the concentration of copper and the temperature constant. To keep a constant pH during the Barth reaction was difficult, but it was achieved by the use of a buffer solution and by adding an alkaline solution during the reaction to neutralise as far as possible the hydrochloric acid formed. Attention was also paid to the fact that the copper should not only always be in solution, but should also always be in the same form ($\text{Cu}(\text{NH}_3)_4$). A curve roughly of the following nature was obtained.



It was found that the best conditions lay between a pH of 9.0 and 9.2 and that it was better to aim for a pH of 9.2 as the curve was not so steep on that side of the maximum. The solutions with the different pH values were made from NaOH, Na_2CO_3 , NaHCO_3 ,

NH_3 , $(\text{NH}_4)_2\text{CO}_3$ and CuSO_4 solutions. In estimating the yield the acid was precipitated with HCl , washed with water, and dried at 110°C on a glass filter.

With regard to the copper catalyst it was found to be quite wrong to expect that on adding copper sulphate solution to the arsenite solution an increase in the amount of copper would produce a corresponding increase in yield. The copper was precipitated more or less rapidly as $\text{Cu}(\text{OH})_2$ and $\text{Cu}(\text{AsO}_3)_2$ and thus had no catalytic effect. It was much more important to see that a sufficient concentration of ammonia was present to keep up the concentration of $(\text{Cu}(\text{NH}_3)_4)$ complex in the arsenite solution. As the ratio of copper to ammonia depends on the pH of the solution the experiments were carried out in such a way that the pH of the solution was kept constant and different amounts of $(\text{Cu}(\text{NH}_3)_4)$ were added. It was found that an increase of the Cu ion concentration over 19 (as far as can be remembered) millimols per litre did not increase the yield.

The temperature of the arsenite solution had little effect, but the yield appeared to fall over 60°C .

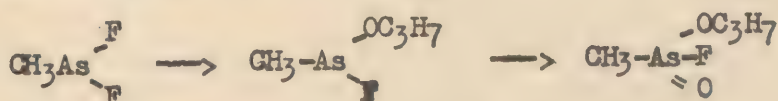
The older method was to heat the o-arsonic acid with conc H_2SO_4 at 80°C . for one half to three quarters of an hour. The acridarsonic acid was precipitated with ammonia, dried and then suspended in HCl in the presence of a small quantity of HI and SO_2 passed into the solution until reduction was complete.

A new method was introduced whereby the acridarsonic acid was not isolated. With good stirring the solution of acridarsonic acid in sulphuric acid was gradually added to a 50 per cent conc. HCl in the presence of KI and SO_2 passed into solution. The precipitated Excelsior was filtered, washed with CH_3OH and obtained in good yield and an excellent state of purity. Further experiments on the technical application were carried out by VIII L and RVIII.

It was understood that Professor Pummerer had been working on an improved method for the preparation of Excelsior and that the conversion of V to VII was carried out in one step with PCl_3 , but no details were known.

Miscellaneous preparations

Attempts were made to prepare the arsenic compound corresponding to Sarin.



This compound was sent for proof without analysis (an unusual procedure) and was found to be ineffective. It was considered that the reaction $\text{CH}_3\text{-As(OC}_3\text{H}_7)_2 + \text{HF}$ might be usable. Hydrofluoric acid and methyl arsenite did not give a good yield. An attempt was also

made to prepare the compounds of the type $\text{O} = \text{As} \begin{smallmatrix} \text{OR} \\ \text{F} \end{smallmatrix}$, but these compounds were too unstable splitting off a molecule of RF with great ease.

It was found that compounds of the Tabun series where the ester group was chlorinated were all very inactive.

Work had been done on the stabilisation of Tabun, but it was understood that no definite results had been obtained. Dr. Dorken, VIII L, who was not available for interrogation, had been dealing with this problem.

Only one compound of the type $\begin{smallmatrix} \text{RO} \\ \text{PF} \\ \text{RO} \end{smallmatrix}$ was made and this was hardly active; the fluorine was very quickly hydrolysed.

Compounds of the type $\begin{smallmatrix} \text{RO} & & \text{O} \\ & \diagdown & / \\ & \text{P} \\ & / & \diagdown \\ \text{RO} & & \text{F} \end{smallmatrix}$ were all found to be much less effective than Sarin.

The preparation of the alcohol $\begin{smallmatrix} \text{Cl} & & \text{F} \\ & \diagdown & / \\ & \text{C} \\ & / & \diagdown \\ \text{Cl} & & \end{smallmatrix} \text{-CH-CH}_2\text{OH}$, was under consideration.

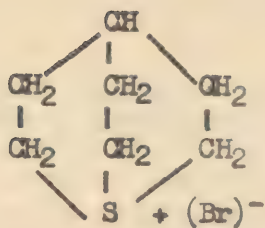
An attempt to prepare the compound, $\begin{smallmatrix} \text{CH}_2\text{CH}_2\text{Cl} \\ \text{CH}_2=\text{CH-N-CH}_2\text{CH}_2\text{Cl} \\ \text{CH}_2\text{CH}_2\text{Cl} \end{smallmatrix}$, from the corresponding alcohol was unsuccessful.

Experiments had previously been carried out on the preparation of the compound, $\begin{smallmatrix} \text{CH}_3 \\ \text{N-CH}_2\text{CH}_2\text{Cl} \\ \text{CH}_2\text{CH}_2\text{Cl} \end{smallmatrix}$, but this compound was considered to be too unstable to be of importance.

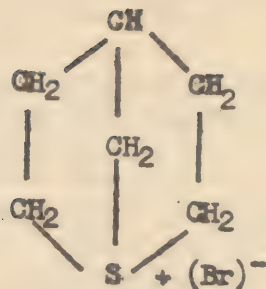
22'-di-iodo-di-ethyl sulphide was prepared and found to be less effective than mustard gas, but it was a well defined crystalline compound and proved very useful for the study of reactions.

Some lead compounds were examined, but attempts to prepare a lead mustard were unsuccessful and the compound $(\text{C}_2\text{H}_5)_3\text{PbCl}$, was found to be no improvement on tetra-ethyl lead.

Considerable interest had been shown in the compounds referred to by Praetorius and Kuhlmann, Ber, 1939, 71, 672, but it was found impossible to prepare the compounds



+



in good yield.

Some work had been carried out on improved methods for the preparation of pinacolyl alcohol, but it was subsequently understood that the I.G. were able to get the corresponding unsaturated hydrocarbon in good yield by a cracking process.

Research Institute F2

This was devoted to Analytical Chemistry under the direction of Dr. Rudolf K  lliker. It had six main laboratories as under:

Lab.1.	Polarimetry	Dr.Ender, Dr.Heinz Vogt.
Lab.2.	Work on Sarin and Tabun	Dr. Johannes Wolf.
Lab.3.	Examination of captured enemy material, HCN determinations, ampoules for storage trials.	Dr. Rudolf Schl��ter
Lab.4.	Mustard gas derivatives.	Dr. Hans Kobs.
Lab.5.	Chamber trials.	Dr. Rudolf Ulm.
Lab.6.	Sarin research.	Dr. K��lliker.

The only members of F2 available for interrogation were Dr. Ulm and Dr. Kobs. The former was concerned mainly with analyses for chamber trials. Full details provided by him for the analysis of the various war gases are included in Appendix I.

Laboratory 4 of F2 carried out investigations into the thermal decomposition of mustard gas and Tabun.

Sulphur dichloride mustard was heated for 300 days at 60  C. in iron vessels when a sludge had separated out and was removed. From the sludge was isolated what was probably the water soluble

$$\text{HFeCl}_4 \cdot \text{S} \begin{array}{c} \text{CH}_2 \cdot \text{CH}_2 \\ \diagdown \quad \diagup \\ \text{CH}_2 \cdot \text{CH}_2 \end{array} \text{S} \cdot \text{H}_2\text{O}, \text{ dithian and a complex of ethylene-bis-}\beta\text{-}$$
 chlorethyl sulphide and ferric chloride. From the liquid layer was

obtained ethylene dichloride, dithian and ethylene-bis- β -chloroethyl sulphone.

Tabun after heating for 3 weeks at 100°C. had decomposed considerably forming hydrogen cyanide, propionitrile and pyrophosphoric acid - diethyl ester - bis - dimethylamide.

It is understood that Dr. Wolf was working on the new methods for estimating Sarin and Soman. Dr. Schlüter was undertaking accelerated storage tests for mustard gas. Ampoules containing the mustard under test were filled with steel filings and maintained at high temperature, and the mustard analysed from time to time by the usual methods. Polarimetric methods for the estimation of Fluorine were under investigation. Also a fluorescent method was being developed for the estimation of Bromine mustard (believed by the Germans to be a component of a U.S. mixture for spraying).

Research Institute F3

F3 was under the direction of Prof. Jung. It dealt with research on physical and physico-chemical subjects, including the structure of smokes, absorption and desorption by charcoal, determination of physical-chemical constants, molecular distillation and optical and X-ray experiments as applied to the inspection of the interior of munitions. A projected research was the radio-active examination of the penetration of filter materials. Only three members were available for interview, Drs. Schweckendick, Wolf and Kasel, from whom the information given below was obtained. Other workers in F3 were Dr. Holm - absorption and desorption by charcoal and Dr. Siemens - Molecular weight determinations.

Methods of generating smokes for laboratory experiments Potassium iodide was much used as the standard substance for laboratory experiments. It was sprayed from solution in methyl alcohol from an atomiser of the scent spray type which had a needle valve control for the liquid fuel at the orifice and an adjustable nose cap for controlling the air flow. Particle size could be varied by altering the strength of the solution. Other smokes used in the investigations were chloro-sulphonic acid dispersed by spraying and zinc hexachlorethane mixture which was ignited. These smokes were regarded as being representative of those actually used in the field. No other smokes had been investigated.

Methods of determining particle size, number, concentration and shape A slit ultramicroscope was used for counting. They preferred to use a large cell with a sharply defined beam rather than a small cell in which the beam boundary is delimited by the walls of the cell. In the latter type, it was considered that losses of particles in the walls occur. They had been investigating the use of an "Iconscope" - a television scanning device for automatic recording of the number of particles. The application of the apparatus was not fully developed since it was required for other more urgent work.

Particle size distribution determinations were made by measuring the rate of fall in a thick walled copper cylinder 125 cm³ capacity weighing 20 kg. Particles were photographed in a Tyndall beam with exposure of 13 secs. The negatives were projected on a screen and the tracks of the particles measured. Sizes were calculated from the Stokes-Cunningham formula. Measurements on 300 particle tracks were sufficient for a complete size distribution. Concentrations were determined by taking samples of Schleicher and Schull filters.

During the past year they had available a Siemen's electron-microscope and Dr. Schwekendick had received special training in its use. This was an electro-magnetic instrument, maximum high tension 104 Kv (controlled to within + or - 3 volts) The valves derived their current from batteries. The resolving power of the instrument was 0.03 microns or less. The specimen holder was made of platinum with an 0.07 mm. hole covered with collodium film. This was exposed in the smoke for 10 or 20 minutes in order to obtain a sample.

By using a very small emission and very high tension it was possible to examine zinc chloride particles. They did not evaporate in the high vacuum, possibly this was due to the formation of a protective film. The particles were spherical or ellipsoidal in shape. SiO₂ formed hollow shells. TiO₂ particles were spherical, and the larger particle often had smaller ones attached over the surface. KI was crystalline.

Transmission of Radiation by smokes A considerable amount of work had been done on the transmission of visible infra red radiation through smokes of the kind described above, the measurements extending up to a wave length of 16 microns. These were designed specially for assessing the performance of infra red viewers (Spannergerät) used by the Army and Navy. The Spannergerät for their experiments was a standard type made by Allgemeine Electricische Gesellschaft (Forschung), Berlin, Reinigendorf. In this instrument the radiation is focussed on a quartz caesium cell, and the electrons are accelerated in an electric field and focussed by electro-static lenses on a green fluorescent screen. It is sensitive up to a wave length of 1.2 microns. They found that the viewer was useless for penetrating smoke screens, but in cases where a target was obscured by dust clouds (i.e. by large particles) considerable assistance could be derived by use of the instrument. A bolometer form of Spannergerät had been used by the Navy for detecting radiation from funnels and Dr. Schwekendick thought it had been made by Zeiss.

For longer wave lengths they had used a photo electric cell sensitive up to 3.5 microns, which had to be cooled with solid CO₂ owing to thermal instability. This was made by Elac (Electro-Acoustic), Namslau nr Breslau. Longer wave lengths up to 16 microns were detected by a bolometer. Absorption coefficients of smokes were measured. In Chlorosulphonic acid smoke, the transmission of 16 microns radiation was 15 times that of visible light.

Dr. Schweckendick could give no information about the relation between scattering of light and particle size. They had preferred to do practical experiments before considering theory. He knew about the work of Stratton and Houghton on scattering by water droplets, but was unaware of the investigations of Engelhard or Freiss (Koll. Zeit) on the polar scattering by small particles. He knew of no methods for producing homogenous clouds.

Measurements of penetration of filters by radio-active indicators and general work on filter efficiency In 1941-42 experiments were made on the penetration of German and Polish filters by KI containing a radio-active indicator. Hydrogen and thorium emanation were bubbled through methyl alcohol. After ten hours the activity was sufficient for making up KI solution, which was sprayed in the usual way. The smoke was absorbed in methyl alcohol before and after passing through the filter and the solutions were evaporated on metal plates which were then placed in an electrometer for activity measurements. Concentration of original cloud was 60-80 mg/m³. Penetration of the German filter was of the order of 0.001% whilst the Polish was 0.1%. The optimum particle size for penetration was about 0.2 microns diameter but little systematic work had been done in F3 on this subject. Filter testing had also been done in F4 with photo electric apparatus using Clark I smoke (Dr. Zeumer). Foreign filters were all so good that there seemed no prospect of securing significant penetration and so little attention had been paid to control of particle size. It is interesting to note that, although the German particulate filter was excellent, some leakage through the outlet valve was found when high concentrations of toxic smokes were encountered.

Stability of smoke compositions Trouble had been experienced owing to the spontaneous combustion of smoke mixtures containing aluminium. A special bomb calorimeter had been designed which could be initiated by electrical thermostatic control at 40°C. The temperature control was effected by means of a resistance bridge and photo-electric actuation from the spot of light from a galvanometer. Temperature of the charging was measured by thermo couples. It was found that after a period there was a rapid temperature rise.

Comment The research in F3 on the physical properties of smokes, although no doubt well conducted, was not in an advanced state. No information which is at all novel has yet been disclosed and there seems to be little indication of work on new lines.

Infra-red absorption by smokes - Research by Dr. Erich Wolf This research was complimentary to that described above which was being done by Dr. Schweckendick, and was commenced in Oct. 1944. The apparatus was being constructed and assembled at F3 Spandau before the move to Raubkammer and no results had been obtained.

It was intended to make measurements of the absorption and scattering of I.R. by smokes in relation to particle size. The main object of the experiments was to gain fundamental information in connection with I.R. photography and the use of infra-red viewers and detectors by the Navy. For detecting and measuring the intensity of long wave I.R. radiation, a Naval instrument known as Donau 60 (probably made by Zeiss and supplied by Wa.Pr.8) was going to be used. Full details of this were not known, but broadly speaking it is a form of sensitive bolometer bridge. The radiation falling on the bolometer is interrupted by a rotating sector and the alternating current of several hundred cycles per sec. thus produced in the bridge circuit is amplified before passing to a measuring instrument.

For near I.R., a Nernst filament lamp was to be used (samples obtained) whilst for longer waves, a high pressure mercury vapour lamp was to be the source of radiation. The radiation was to be split into two beams by mirrors. These mirrors were made from spluttered aluminium on glass. A number of them have been retrieved from the Spandau stores and are being sent to U.K. They are of very high optical quality. One beam was to pass through the cloud whilst the other was to be used as the comparison standard and had the same optical path (25 m.). Both beams were then to pass to a monochromator so that absorption of different wave lengths could be studied. The two beams then passed to the bolometers in the arms of the bridge. For wave lengths up to 2 microns, a quartz prism was to be used whilst, up to 6 microns, a potassium bromide crystal was to serve. The monochromator has been retrieved, but unfortunately the quartz prism and the crystal which are particularly valuable have not been found. The smoke chamber was to have quartz windows some 20 cm. square and 2 mm. thick. For long wave lengths rubber windows, 1/100 mm. thick were to be used. Paraffin was to be the source of smoke.

Emission spectra of vesicant vapours A study was commenced in Dec. 1944 of the emission spectrum of vesicant vapours. The work was undertaken by Hans Joachim Käsel, who had worked for two years under Prof. Schuler at the Kaiser Wilhelm Institute, Dahlem. There he had been investigating the spectra of benzene, toluol and xylol and the same technique was employed in the present study. A spark tube about twenty cm. long was used. It had two side limbs, one holding the vesicant and the other being cooled in liquid air. The vapour was transferred from one limb to another through the main spark discharge tube by a stream of hydrogen and in that way a continuous stream of undecomposed molecules was maintained. The voltage drop across the tube was 4,000 obtained from a transformer. No significant results had yet been obtained. The investigation was of an entirely fundamental nature designed to obtain information regarding molecular structure. It was complimentary to another study being undertaken by Fraulein Basch on the Roman spectra of vesicants.

Other Research work in hand It was proposed to measure the penetration of rubber and other materials by the use of radio-active Mustard gas. They intended to make radio sulphur by bombarding chlorine with β rays.

Research Institute F4

F4 Director :- OBR Dr. Zeumer
Assistants Dr. Leopold
Dr. Sperling.

The Research Institute F4 could well be considered as the research laboratories for Group X of Wa. Prüf. 9. No member of F4 was available for interrogation, but it is understood that the chief subjects studied were as follows :-

(a) Examination of substances which might have a deliterious effect on the internal combustion engine e.g. dirty the plugs, cause corrosion, disturb oil film in cylinders etc. After 2 years work no practical results had been obtained, the best substance found being ethyl fluoroacetate.

(b) A study of possible incendiary and sabotage materials.

(c) Protection against incendiaries.

(d) Fine dust explosions.

(e) The use of insecticides.

(f) Sticky materials for the attack of tanks.

(g) Field trial technique.


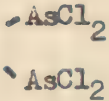
(h) Possible methods of using war gases which are thermally sensitive and cannot be detonated in the usual manner.

Research at Universities etc.

A considerable amount of the research work for Wa. Prüf. 9 was carried on at the various Universities and Technical High Schools etc. and this work was controlled and co-ordinated by Group V. The scope of the work is indicated briefly in Table I.

In addition much work had been carried out by Professor Steinkopf, now retired, and by Professor Ruff who has since died.

Some compounds said to be of particular interest were :-

Compound.	Prepared by.	Properties.	Reason not used.
Cl_2As  AsCl_2 + substitution derivatives H_2C 	Prof. Steinkopf) Prof. Hans Fischer	Practically no smell and good green cross effect	Scarcity of Arsenic and difficulty of preparation on a big scale.
Selenium and Tellurium compounds, e.g., SeOF_2 .	Prof. Hückel and Prof. Brintzinger.	Strong green cross effect as well as effect on skin.	Almost complete Absence of Selenium and Tellurium in Germany.
$\text{F.CH}_2.\text{CH}_2.\text{OH}$ $\text{F.CH}_2.\text{CHO}$ $\text{F.CH}_2.\text{COOH}$ $\text{F.CH}_2.\text{CO.R}$ (R = C_2H_5 , C_3H_7 , and $\text{CH}_2=\text{CH}=\text{CH}_2$) $\text{F}_3\text{C.COOH}$ and especially Calcium salt.	Prof. Ruff and Prof. Hückel	Strong green cross effect quickly produced.	Difficulty of providing raw materials, but chiefly because Tabun was considered much better.

APPENDIX VI

TABLE I

C.W. Research Work carried out at Academical Institutes in Germany

No.	Name.	Place.	Institute.	Work carried out.
1.	Prof. Bockemüller	Berlin (formerly in Würzburg and went back there in February).	Akademie der Luftwaffe.	Synthesised a series of Fluorine compounds.
2.	Prof. Bohme.	Berlin.	University.	Compounds of mustard type also undertook synthesis of required compounds.
3.	Prof. Hahn.	Berlin.	University.	Studied break-down of filters with radio active substances, for example KI fog from radio active iodine. Worked directly with Prof. Jung F3.
4.	Prof. Hellberger.	Berlin.	Tech. H.S.	Used for the employment of Prof. Trochimovsky. See 6.
5.	Dr. Kruger.	Berlin. Now returned to Ahlbeck.	Zellwolle Forschungsinstitut.	Worked chiefly directly with Group II on materials to give protection against mustard.
6.	Prof. Trochimovsky	Berlin.	Tech. H.S.	Born in Ukraine and found in Warsaw brought to Berlin as he had experience of work on fluorine compounds. Made some fluorine compounds but did not have much success.

No.	Name.	Place.	Institute.	Work carried out.
7.	Prof. Hückel	Breslau (now evacuated to Göttingen).	University.	Systematic study of fluorine compounds calcium salt of trifluoroacetic, fluoro-ethyl alcohol etc. Also fluoro phosphates.
8.	Prof. Friese.	Brunswick.	University.	Had just commenced work on arsenic compounds of quinoline.
9.	Prof. Manegold.	Dresden.	Tech. H.S.	Colloid Chemist worked on mustard and nebel-saure foams.
10.	Prof. Frederick Muller.	Dresden.	Tech. H.S.	Suitable substitutes for smoke generators.
11.	Prof. Simon.	Dresden.	Tech. H.S.	Search for suitable catalysts for impregnation of charcoal against cyanogen chloride. Was asked to study American active charcoal.
12.	Prof. Pummerer.	Erlangen.	University.	Worked on Excelsior. New method of effecting ring closure, reduction and chlorination of Merodansaur to Ex all in one stage with PCl_3 . Also worked on simplification of synthesis of Merodansaur. Methods of estimating how much charcoal filter had been used.
13.	Prof. Gerhardt Jander.	Greifswald.	University.	Aerosol problems, particles, size, etc. study of hydrolysis of aerosols. Vapour pressure measurements.

No.	Name.	Place.	Institute.	Work Carried out.
14.	Prof. Remy.	Hamburg.	University.	Micro methods for testing active charcoals.
15.	Prof. R. Kuhn.	Heidelberg.	Kaiser Wilhelm Institute,	Pharmacological effect of new phosphorus compounds. Synthesised Soman. Tried $C_4O_4H_4O$ as antidote for H_g . Expected Tocopherol to be useful against fluorophosphates as these cause "Creatinurie" but this does not appear to have been successful. Micro methods of detection. Found there were 5 or 6 different modifications of IM and also of Ex . Was trying to get micro detection methods for fluoro phosphates.
16.	Prof. Koffler.	Innsbruck.	University.	Selenium compounds, stink compounds synthesis and stability of phosgene oxime and similar compounds. Nitroso compounds.
17.	Prof. Brintzinger.	Jena.	University.	Worked directly for Group III on problems of mustard contaminated food stuffs.
18.	Prof. Schwarz.	Kiel.	Nahrungsmittel Institut.	

19.	Dr. Erdres.	Munich.	Brauerer Wissenschaft- liches Institut.	<p>Whether possible to get yeasts or other fungi which would attack mustard or nitrogen mustard. Found it was possible to raise types which would decompose mustard and nitrogen mustard but not in sufficient quantity to be practical.</p> <p>Did not do much work but knew Von Sicherer well. Had an assistant Dr. Endenann who was sent to Gendorf to help with difficulties of H manufacture.</p> <p>Asked to synthesise CH_2, As Cl_2 As Cl_2</p> <p>Made from acetic acid and arsenic trichloride. This point was sent in as a suggestion by a School-master who had made it under primitive conditions. It is said to be as poisonous as phosgene, to have no lachrymatory effect and very little smell.</p> <p>Worked on arsine and whether there were different forms of this compound said to have found a solid form.</p> <p>Properties of charcoal. Action of CO at low temperature.</p> <p>Studied night detector powder, break-down of charcoal filter.</p>
20.	Prof. Hans Fischer	Munich.	Tech. H. S.	
21.	Prof. Hieber.	Munich.	Tech. H. S.	
22.	Prof. Manchot.	Munich.	Tech. H. S.	
23.	Prof. Scheibe.	Munich.		

No.	Name.	Place.	Institute.	Work carried out.
24.	Prof. Fricke.	Stuttgart.	University.	Sought CO catalysts free of copper, also one which was not so sensitive to water. Cobalt sulphate said to have been a possibility.
25.	Prof. Ebert.	Vienna.	University.	Thickeners for mustard and also HCN. Substitutes for asbestos in filter.
26.	Prof. Ulrich Hoffmann.	Vienna.	Tech. H. S.	Improved performance of active charcoal against cyanogen chloride.

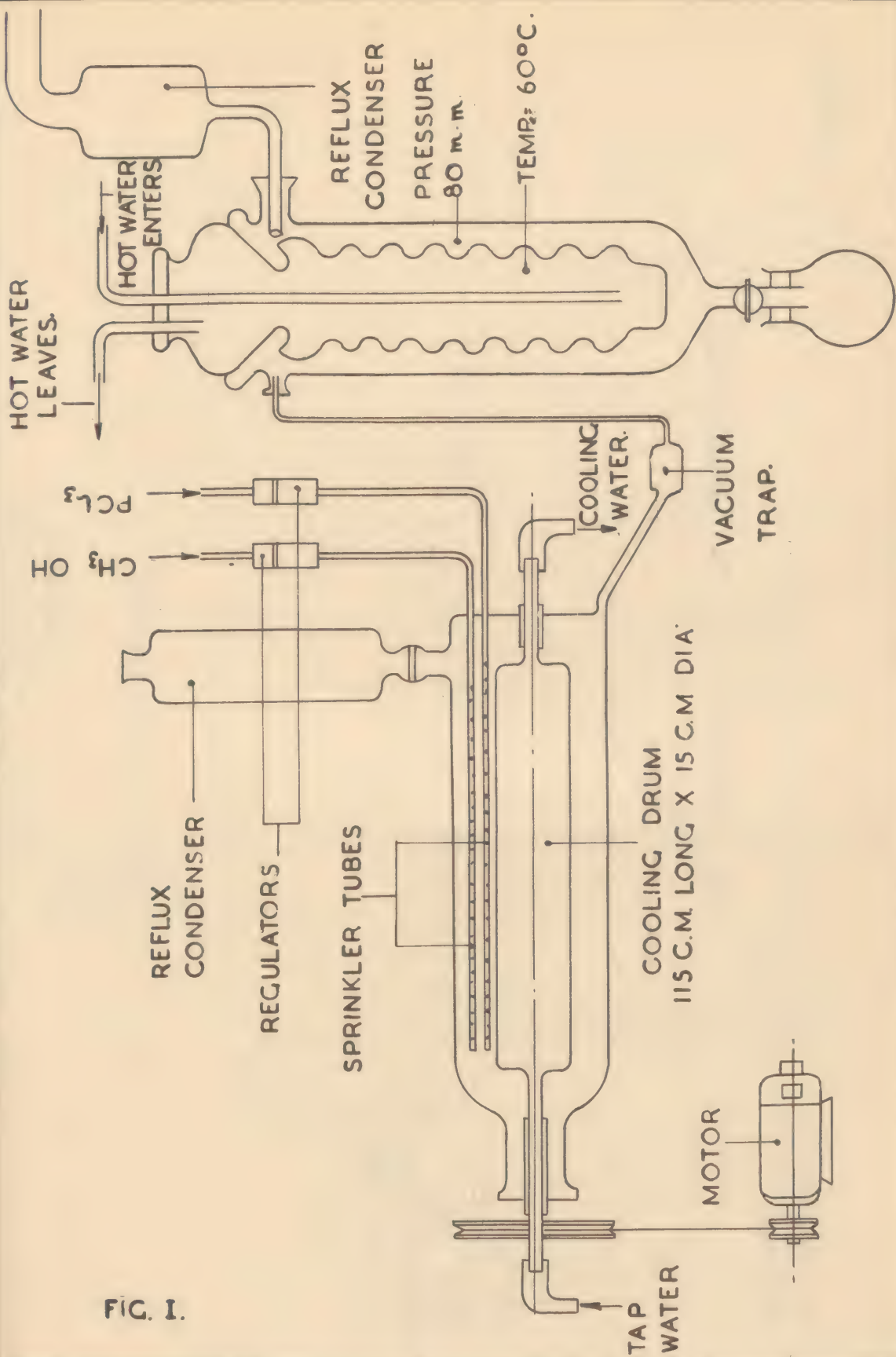


FIG. 1.

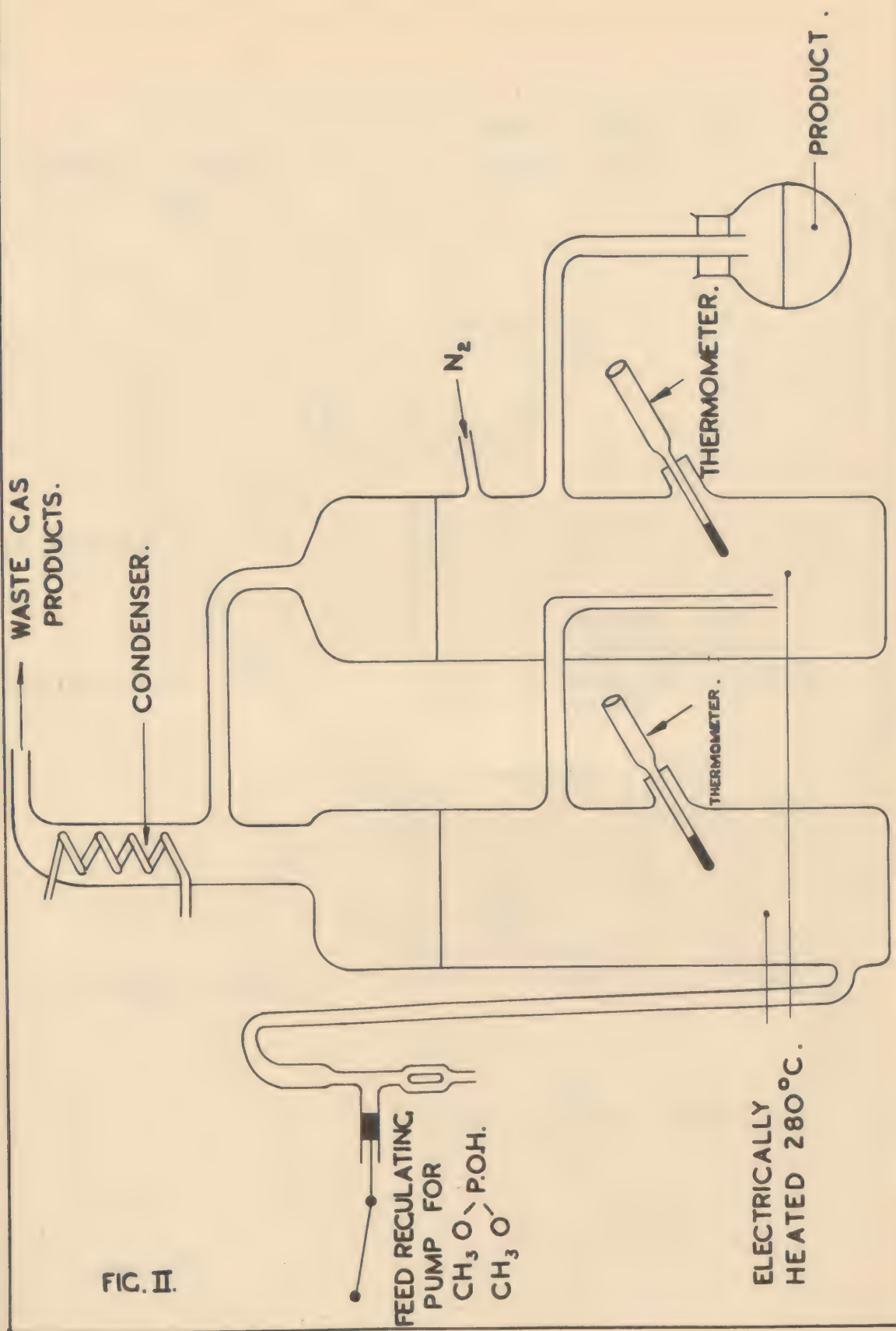


FIG. II.

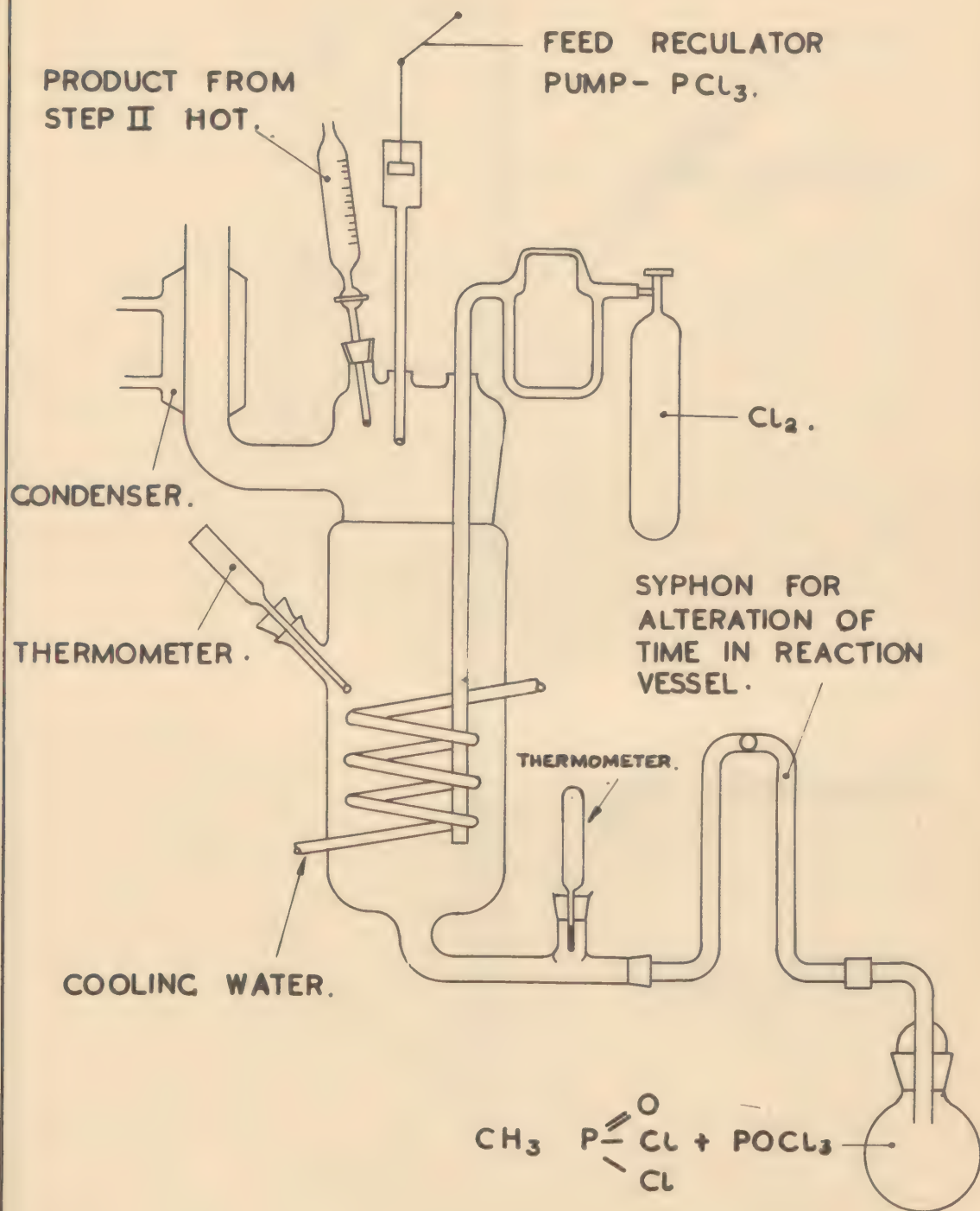


FIG. III.

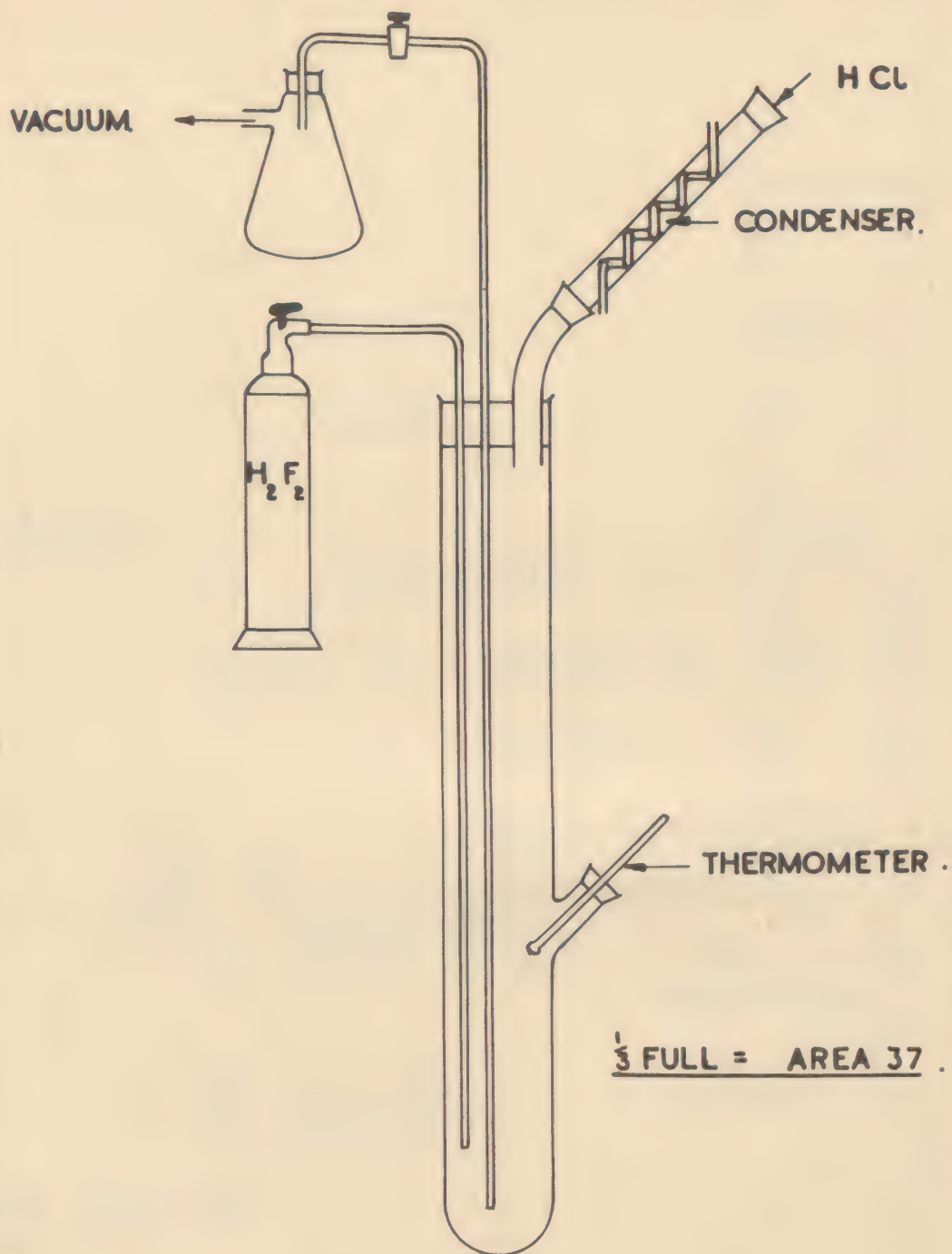


FIG. IV.

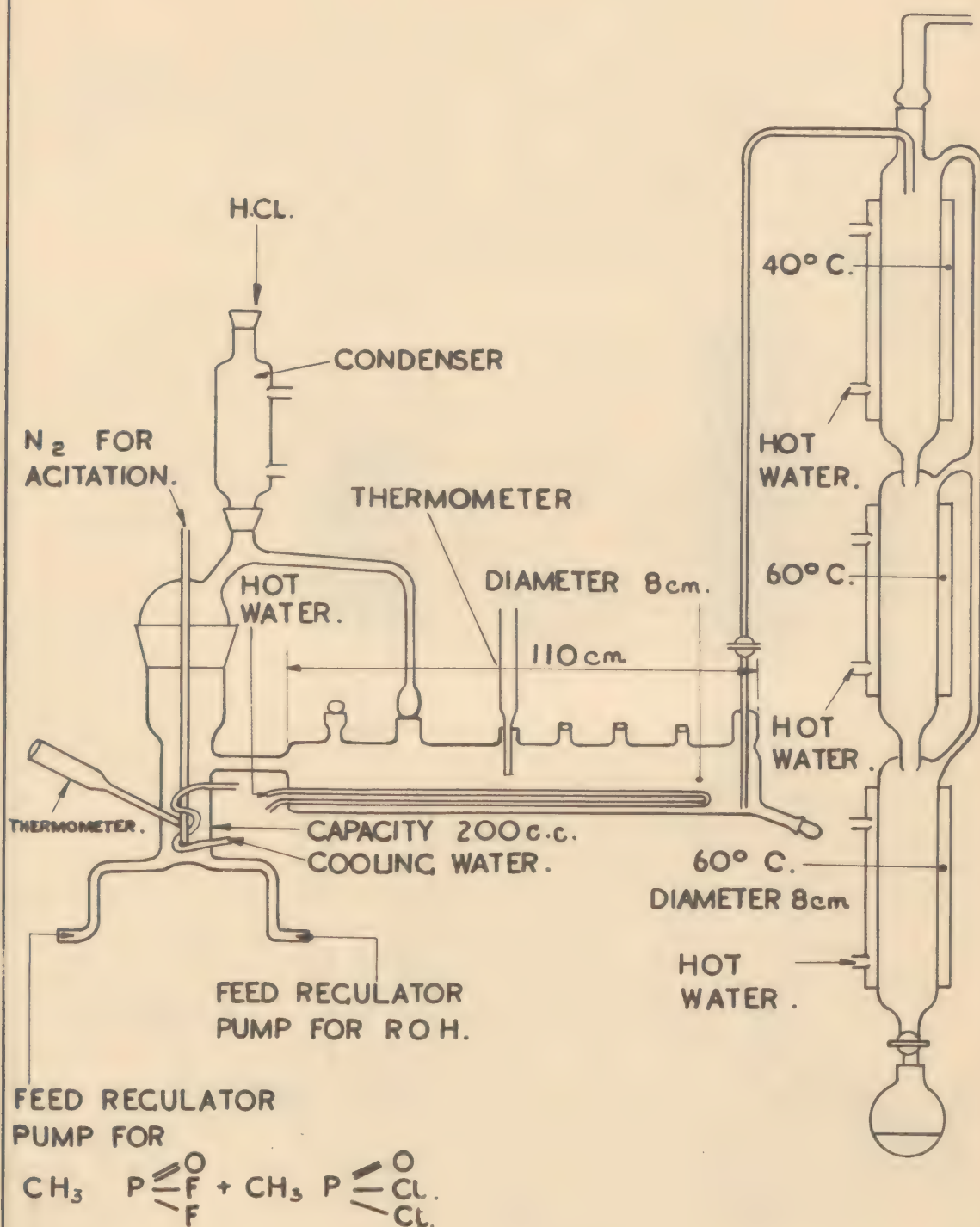
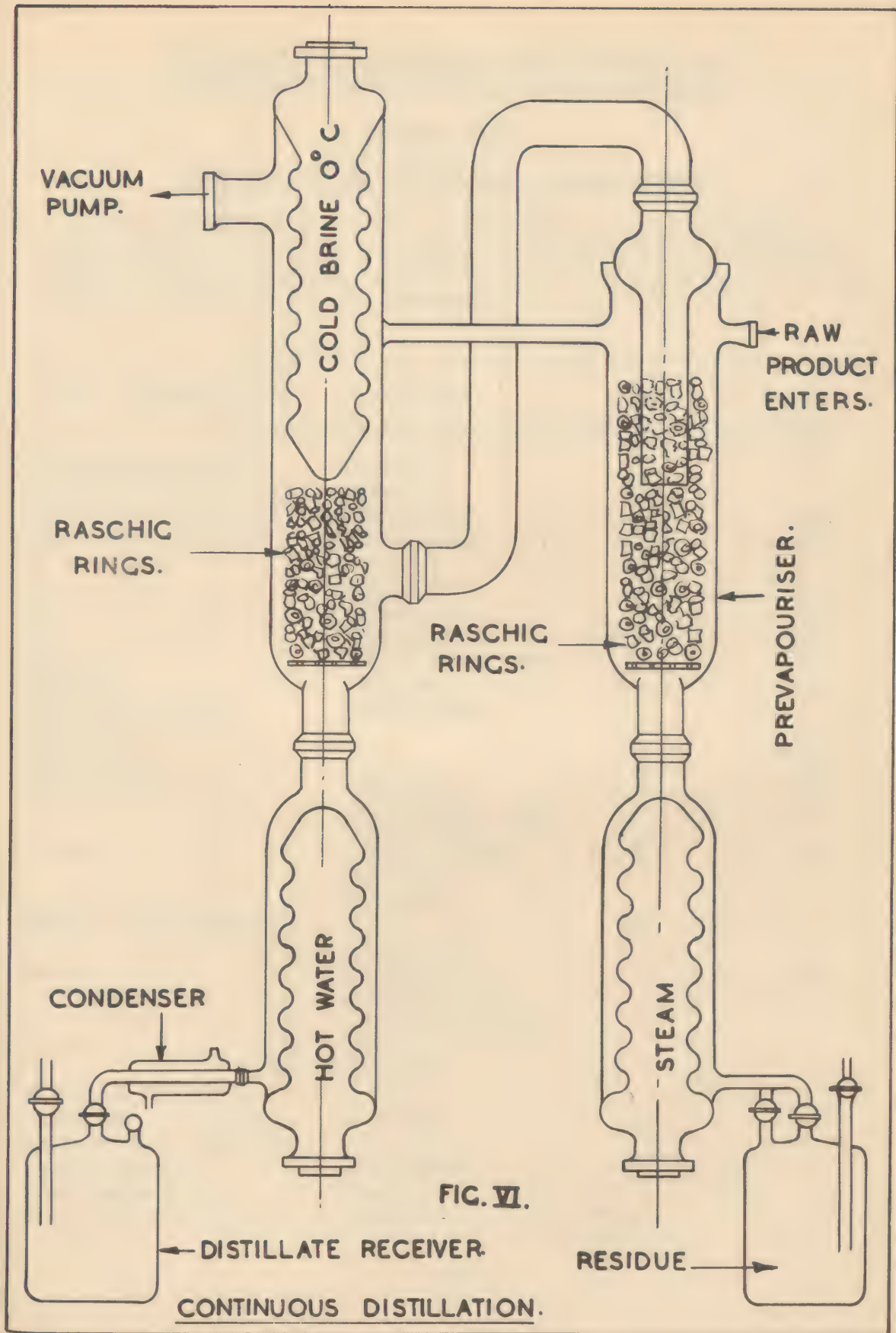


FIG. V.



Investigation of Chemical Warfare Installations
in the Munsterlager Area, including Raubkammer

APPENDIX VII

SYNONYMS FOR GERMAN CHEMICAL WARFARE AGENTS

Several different codes are or have been in use for chemical warfare agents in Germany, and these are given in tabular form below. The last column is a local code which was in use for a short time and which may occasionally be encountered.

Usual or Chemical name.	Code Name .	Code lettering.	Local Code.
Chloroacetophenone	O-salz	A	os
Bromomethylethylketone	BN-stoff		
Methyldichloroarsine	Medikus		md
Phenyldichloroarsine	Pfifficus		pf
DM	(Azin		
	(Adamsite	M	az
DA	Clark I	CI	oc
DC	Clark II	CII	cz
DA Oxide	Clark oxide, Dora		
Hydrogen cyanide	Bauxin	Bx, P	bx
Potassium cyanide	Bauxin salt		
Cyanogen chloride		J1	ie
Phosgene		F	fg
Diphosgene	Perstoff	H	po
Chlorpicrin	Nitrolsaure, Klop		ns
	(Neuler Grün-		
Tabun	{ kreuz Stoff,	G	tb
	{ Gelan I		
	{ Trilon 83		
Tabun - chlorobenzene		GA	
	(Gelan III		
Sarin	{ Trilon 46,		sr
	{ Verbesserter		
	{ Grunkreuz-stoff		
Arsine	{ Senal		
	{ A-stoff		
Aluminium Magnesium			
Arsenide	Aeroform		
5-chloro-5:10 dihydro- arsacridine	Excelsior	Ex	ex
Iron pentacarbonyl	Methen		
Phosphine	Penitot		

Phosphorus oxychloride	oxysaure		
Thiodiglycol mustard	oxol-lost	O	ij
Sulfur Dichloride mustard	D-lost	D	
Mixture of chlorophenyl arsines	Arsinöl	A	
Thiodiglycol mustard- chlorobenzene 1:1	Winterlost	C	
Anthracene oil		R	
Mixture mustard and Arsinol	Winterlost	OA, B.	ja
Mixture mustard and anthracene oil	Winterlost	OR, L	jr
British HT		OB	jb
Mixture of mustard and dialkyl mustards	Gemischtelost	OM	jm
Thickened mustard	Zählost	Z	
Thickened mixed mustards		ZOA D	
		ZOR	
		ZOM E	
		ZOB	
Italian mustard		JD	
" arsinol		FDA	
" Winterlost		JD/FDA	
Sesquimustard	(Doppel-O	DO	
	(Doppel Omega		
Trichlortriethylamine (HN3)	Stickstofflost	T9 K	in
Phosgene oxime	Kanton		Mt
Lewisite 1			li
Lewisite 2			lg
Lewisite 3			ld
Chlorine trifluoride	N-stoff		

Investigation of Chemical Warfare Installations
in the Munsterlager Area, including Raubkammer

APPENDIX VIII

NEBELTRUPPEN.

The organization of the Nebeltruppen (Smoke troops) is given in Table I.

At the end of the War there were 9 Brigades of Smoke Troops (Werferbrigaden) of 2 Regts. each. Originally the Smoke troops consisted of independent batteries (abteilungen) either for projectors. (Nebelwerferabteilungen) or for decontamination (Entgiftungsabteilungen). As result of expansion in this arm of the service larger units and formations were made in the course of the war. The expansion can be followed by the increase of the order of battle of the Smoke troops as under :-

	1935	36	37	38	39	40	41	42	43	44	45
Nebelabteilung (Smoke batteries)	1	2	2	4	5	5	8	21	21	48	52
Entgiftungsabteilung (Decontamination batteries)					5	5	5				
Road decontaminating batteries							3	3	3		
Werfer Regt.								7	7	16	18
Werferlehr Abteilung (Batteries)			1	1	1	2	2	3	3	6	6
Brigades								1	4	8	9
Werfer Ersatz Regt.										3	3
Mountain Nebelabteilung Smoke batteries.								1	1	1	1

There were some 5 Decontamination Batteries in existence in June 1941 when there was some fear of the Russians resorting to C.W. After August 1941 when the Russians were jettisoning their respirators, the Decontamination Batteries were all converted to Werfer Batteries.

The Nebeltruppen are G.H.Q. Troops (Heeres Truppen).

Recruits

The recruits for the Nebeltruppen are taken on strength by the Kommandantur der Nebel Truppen i. der Ersatz Heeres under Gen. Major Graewe with H.Q. in Raubkammer. There are 3 Ersatz Regiments of the Nebeltruppen stationed at Bremen, Münster (Süd) and Donauworth.

Under the aegis of the Werfer Ersatz organization, complete abteilung (batteries) were trained for posting to the field Army. Also shattered and depleted units from the front were posted in for replacement and reforming.

The General der Nebeltruppe, Ochsner at OKH (until he was promoted to OKW towards the end of the War) had a visiting right, (besuch recht) to see and advise on the training of the Werfer ersatz troops. Alteration of tactical training would also originate from his office (amt) through OKH (Ersatz Heeres) and Inspection 9. and he passed down to the training establishments.

Nebeltruppenschule - Celle

The smoke troops' school is at Celle adjoining the Gas Defence School. Since 1943 it was divided into three wings :-

- Lehrstab A - Officers Wing
- Lehrstab B - N.C.O's Wing
- Lehrstab C - Technical Wing

The school is partly a technical school and partly a Smoke Officers' Training Centre.

The school had been evacuated and occupied by a PW (X) camp when the team arrived. There was no staff or documents left.

Officers' Wing

There were various courses.

Company Commanders courses lasting one to two weeks were held three or four times per year.

Junior Officers courses lasted longer and were held four to five times per year.

No offensive C.W. tactics were taught as far as ascertained.

N.C.O's Wing

Courses for Werfer Regt. N.C.O's were run consecutively. At one time in 1944 this wing was stationed at Truppenlager Raubkammer.

Technical Wing

This wing ran rather long courses of one year's duration and longer.

Schirrmeister (Ch) course	(Sgt. i/c chemical stores)
Oberschirrmeister (Ch) course	(Sgt. Maj. i/c chemical stores)
Inspector (Ch) course	(Lt. i/c chemical stores)

All these courses covered the use, maintenance, repair, and indenting of chemical equipment. Students qualifying were posted as Schirrmeister (Ch) at Werfer Regt. Units.

To qualify for an Inspector (Ch) course or Beamter course, candidates had first to have passed the Schirrmeister course.

Candidates for the Inspector (or Beamter) course were usually soliders with 2 years completed service in the ranks. The course was therefore equivalent to an O.C.T.U. (or O.C.S. in U.S. Army) course for senior N.C.O's to qualify them for junior officers' rank in administrative branches of the Army.

Lehrstab C. The gas equipment N.C.O. courses lasting originally over a year were progressively shortened to meet the requirements for more trainees to post to the expanding ranks of the Smoke troops. Course No. 9 ran for ten months, and subsequent courses ran for five months. There were also courses of different duration for active and reserve personnel.

On the Schirrmeister and Beamter courses students were taken out once to see a Nebelwerfer shoot demonstration. No offensive C.W. tactics were taught.

Stabsapotheker, Feldlaborchemiker, and C.W. courses for medical officers were apparently held at the Gas Defence School, Celle, next door.

Feldlaborchemiker

To every Decontamination Battalion was attached a Field Lab. and chemist. It was never settled what chemical standing these officers should have. Some were Baurat chemiker, but some were only Stabsapothekers. After the conversion of the Decontamination Abteilung (Batteries) to the Werfer Abteilung (Batteries) in August 1941,

some three to four Field labs. were retained in Russia. They were under the command of the C.O. Nebelwerfer Regiments, and were attached on his orders to Div. H.Q. or moved if necessary forward.

The Feldlabor equipment did not stand up well to the bad Russian roads, and designs were being drawn up for a new field lab. set to make use of the experience gained in Russia.

With the conversion of the Decontamination Abteilung (Batteries) to Werfer Abteilung (Batteries) most of the trained C.W. personnel were dispersed. After that date the Germans were not in a position to deal with a sudden outbreak of C.W. Apart from the few Feldlabor-chemiker and the unit Gabos - who were only given a 10 - 14 day course in A/G training - they had no C.W. troops.

The Technical Wing - Lehrstab C - of the Nebeltruppenschule moved to Raubkammer in March-April 1945, and later evacuated to Donauworth.

Nebel Werfer Lehr, Regt. 2.

This Regiment was permanently in the Celle and Raubkammer area. The Regt. H.Q. under Oberst. Lt. Böhme, and Abt. I. W. Lehr Regt. 2. were at Celle. Abteilung II and III were stationed at the Truppenlager (or Nebellager) of the Truppenübungsplatz Raubkammer bei Münster, under the Area command of Gen. Maj. Richter.

In the past these Abteilungen II and III were standing troops and carried out training with trial weapons, clothing and equipment. Later, owing to manpower shortage, personnel on the strength were posted out to field force Werfer Regt. The Nebel Werfer Lehr Regt. I though still retaining a connection with Celle was permanently on the Eastern front.

At the Nebellager there was a good museum of all Werfer equipment. The following was displayed :-

21 cms PzW.42

15 cms three barrel NbM.

Layout of 28/32 cms. S.W.g.41.

28/32 S.W.g. mounted on a sledge.

All smoke acid equipment used by Nebeltruppen with all spare part boxes.

Meteorological equipment for Nebeltruppen.

Samples of Russian chemical bombs.

Samples of mortar shaped Russian rockets with projector.

Samples of long rockets, Russian, fired from long rails.

Samples of Russian heavy rockets like the German 28/32 cm. Wk.

Sections of all Werfer amm.

Owing to the occupation of the Nebel lager by a succession of tenants, there was nothing left of the Museum, and all the sectional amm. had been thrown on a junk heap.

In some of the store sheds were found samples of the Hawig Schwimm pump used to fill the Decontamination vehicles. An installation for the regeneration of collective protectors was found. All decontamination vehicles had been evacuated. Copies of "Gasschiessen Alle Waffen" were reported to be at the Nebellager, but none were found.

The Lehr Regt. at the Nebellager carried out trials of respirators and A/G clothing - and of methods of detection, decontamination and traversing of ground contaminated with Bulk contamination vehicles, portable Spraying canisters, chemical mine (10 l. Sp.Bll.37) and aircraft mustard spray.

One troop specialized with Detector Dogs. These were not successful with the troops as they could not be bothered with them. Another troop specialized in horse decontamination.

For these trials, the Nebel truppen had the benefit of the advice and supervision of the interested branches of the Heeres Versuchsstelle, R.III for decontamination and detection, R.IV for the vehicles, and R.IX for the horse trials.

The traversing trials were adequately realistic - troops had to traverse a course of some 6 kms. taking about 2 hours. They were clothed in light A/G suits. The course included one belt of contamination and scattered islands of contaminated ground. They were required to lie down on the contaminated ground and fire their rifles, open lanes of decontamination, reconnaissance with dogs and detector powder the islands of contamination, and finally go through the processes of decontamination of personnel and clothing. Such trials were held only 2 or 3 times a year.

Werfer Shoots

There was a Liaison Officer (Nebeltruppenschule Verbindungs Offizier) at the Nebellager who arranged for the dating of Training ranges and the supply of weapons, ammunition, and maintenance personnel for the shoots required for students from Celle. Any of the three ranges, Raubkammer bei Münster, Münster-Süd, or Bergen as available were used. From the Liaison Officer's files which were captured it is apparent that only HE and smoke amm. were used for these school shoots.

It does not appear that the Lehr Regiment at Raubkammer ever shot chemical rockets other than smoke in Regt. training.

Trials with chemical filled rockets seem only to have been carried out by Heeres Versuchsstelle though doubtless Werfer weapons and firing crews would have been detailed for the trials from the Nebeltruppen at the Nebellager.

Records of the existence of the following ammunition has been found:-

30 cm. Wurfkörper, Green ring, 30 cm. W.K.Gn. fillings:
CG, AC, Tabun, Lost.O.

12 cm. W.gr. 42 Kh Filled Nb
" " " " Blue ring 1
" " " " Green ring 1
" " " " Green ring yellow
" " " " Blue ring 2 (range C. 60000 m.)

30 cm. W.k.Gb. mustard filled for land contamination, range 4-6000 m.

10 cm. W.gr. 40 w.Kh. Blue ring 2. Filling solution of Clark I in Arsinol. Range 6000 m.

10 cm. W.gr. 40 w.Kh.Gn. filled with Lost O in 10 cm. WGN 40 w.Kh.Gn.Gb.

10 cm. W.gr. 40 W.Kh.Gn. filled with T9(HN₃) in 10 cm. WGN 40 w.Green ring 1.

10 cm. W.gr. 40 2B Gb. filled 620 ccs mustard for ground contamination.

10 cm. W.gr. 40 2B Gn 2 filled 620 ccs T83 (Tabun?)

32 cm. W.K.Eg. filled 50 litres Lesantin for decontaminating area 6 to 12 sq. m.

15 cm. W gr. 41 w.Kh.GnGb filled Lost O

15 " " " " " Green ring 1 filled T9 (HN₃)

15 " " " " " Green ring 3 filled Tabun

None of this amm. has been found, though some 30,000 15 cm. WK DOV have been filled by Nebelfulstelle, Münster Nord. They contained thickened mustard and may be at H.Muna Münster Ost. There were 75 Munitions store houses at Breloh which were intended to hold K munitions for Nebelwerfers. Many of these houses were converted to accommodate personnel, and to house captured Italian weapons. No Nebelwerfer ammunition has been found at Breloh.

Training.

No instructor Werfer Regt. officers have been found to interrogate. Only a few Inspectors who went to the Technical Wing to qualify for Beamter appointments and who did not get posted to Werfer Regiments have been interrogated. A file belonging to Major and Abteilung Chef Baron von Freyberg has been captured giving details of training programmes for different Werfer Ersatz Batteries.

It appears that practically all activities connected with the Nebeltruppen were concentrated in the Celle and Münster areas.

Celle was both the site for the Nebeltruppen school, the Nebeltruppen Regimental depot, and the O.C.T.U. for Nebelwerfer officers.

The training for Werfer Regiment officers was carried out intermittently with interpolated periods of service at the front. Recruits came first to the school or depot for 3 months, then were sent to the front for 3 months, then returned to the school for a second period of 3 months training, and then became officers after a further period of duty at the front.

The training was run very much on artillery training lines.

The recruits were given the standard A/G training, but it was expected that smoke troops would become models of A/G training to other troops. Personnel of decontamination batteries however necessarily required additional A/G training. No evidence has been found that any C.W. offensive training was given.

In the south part of the town of Celle there were other barracks built in the same style as the buildings of the school. From the fact that in the garage annexes were found some Nebelwerfers and amm. it would appear that some Werfer units were stationed there. Also near by was found a large store of all A/G equipment and much Nebelwerfer spare barrels. The quantity of A/G equipment found may have represented the equipment carried by Decontamination Abteilung (Batteries) or an A/G equipment Park (Gasschutz Geräte Park).

Personalities

Ochsner, General.	General der Nebeltruppen at O.K.H. later at O.K.W.
Scherer, Oberst.	Assistant to Ochsner at O.K.H.
Graewe, Gne.Maj.	Kommandant der Nebeltruppen i. d. Ersatz Heeres.
Richter, Gen.Maj.	Kommandant der Truppen Ubungs Platz, Raubkammer bei Münster.
Stroh, Oberst.	Nebeltruppenschule, Celle.
Totsihels, Oberst.	Nebeltruppenschule, Celle.
Grosse, Oberst Lt.	O.C. Technical Wing, Nebeltruppenschule, Celle.
Bohme, Oberst.	C.O. Werfer Lehr Regt. 2. HQ Celle.
Gloy, Major	Werfer Lehr Regt.2. Celle.
Schuekraft, Oberst.	Celle.
Baron von Freyberg, Major.	O.C. of a Training Battery.

Vehicles

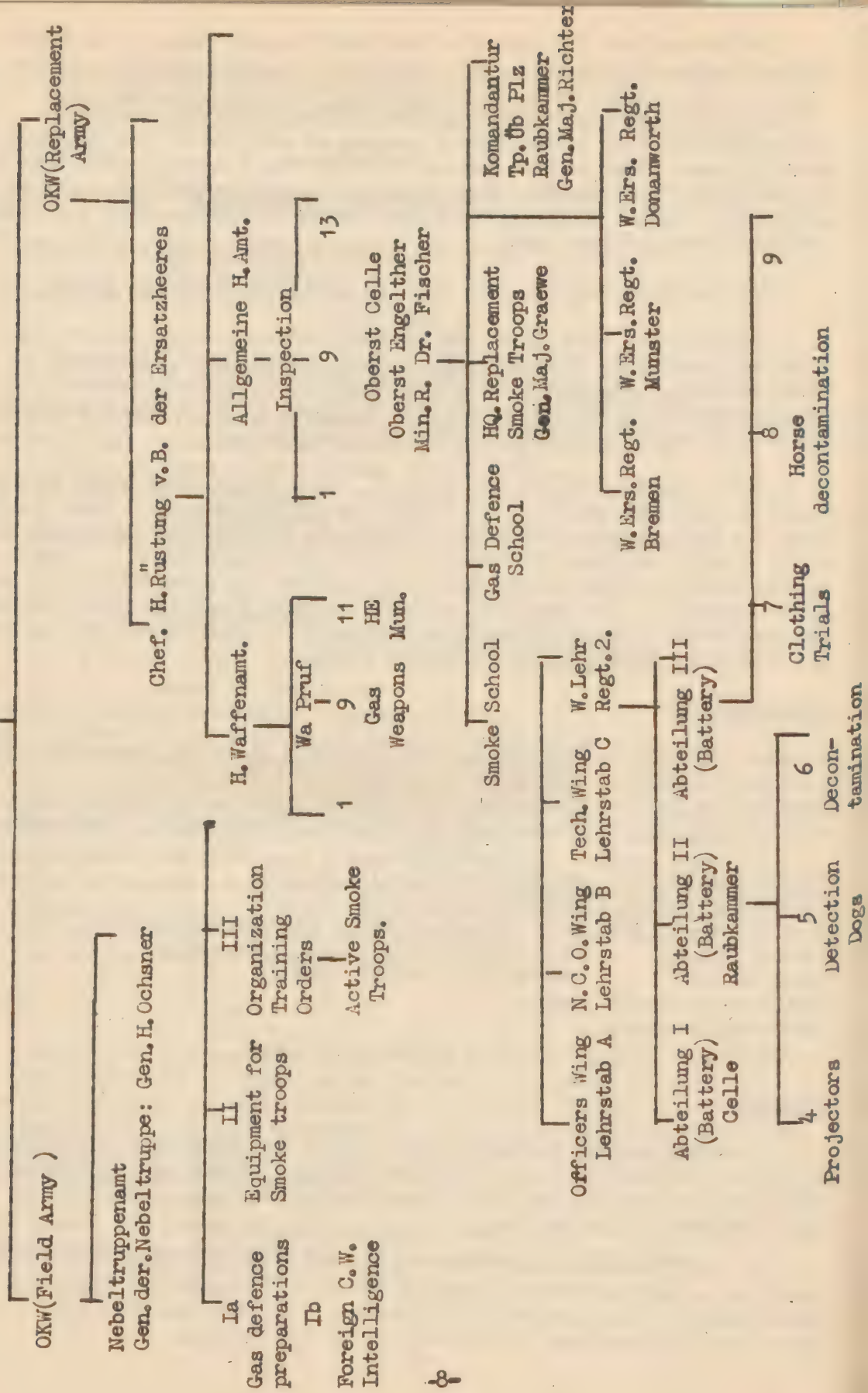
Decontamination Batteries had clothes decontamination vehicles KJ293 and Hot water heating vehicles KJ294. These were withdrawn in 1939 and allotted to the Troop Decontamination Coys. (TEK) of the Sanitary arm of the Service.

It was foreseen that Nebeltruppen would be provided with KJ292 which is a smaller vehicle, and is fitted to provide hot water and to decontaminate heavy rubber A/G clothing. The vehicle from the Nebellager, Raubkammer, was evacuated by the Germans.

TABLE I

Organization of Smoke Troops

OKW



Investigation of Chemical Warfare Installations
in the Munsterlager Area, including Raubkammer

APPENDIX IX

MISCELLANEOUS INFORMATION

1. Gas Munition dump at Scheuen (Heeres Munitions Anstalt, Celle)

Location About 1 mile E. of Scheuen which is 6 km. N. of Celle on the Celle - Sulze road.

Description This was an ammunition dump covering several square miles in area. The ammunition was stored in 100 bunkers partially underground with thick concrete roofs, covered with several feet of earth, and overgrown with vegetation including small trees. Each bunker had two sets of steel double entrance doors, one at each end approached by a flight of steps, and had a capacity of approximately 150 tons. Bunkers were separated by distances of about 100 yards. The area was well wooded. Roads, mainly of well laid macadam and railway lines served the bunkers.

There were also large workshops, filling shops and offices near the entrance to the area.

Gas Munitions No gas munitions were stored at Scheuen until about 3 weeks ago when quantities were brought from Prebus near Meckleberg. These included some shell with green and yellow rings, but we were told that these shell were hurriedly evacuated with instructions that they were to be sent to Wettenberg or, failing that, to be dumped in the Elbe.

The labour for the dump came from a camp of foreign workers, mainly Belgians, situated a short distance away across the main railway line.

The types of gas munitions found were as follows;

Chemical mines (10 litre)	Yellow ring
250 Kg. Bombs	2 yellow rings
250 Kg. Bombs	2 green rings
15 cm. shell	Blue ring
10.5 cm. shell	White ring
15 cm. shell	White ring

(Action No samples of shell or bombs were taken, similar types have been discovered elsewhere and steps taken for examination of their contents. The area is now occupied by No. 88 Group T.A.F. and the B.D. Officer (F/Lt. Cartwright) of B.D.U. No. 6225 was shown the gas dumps and made aware of the probable contents of the munitions).

2. Chemical Shell Dumps at Munster Ost

This Ordnance Depot about $1\frac{1}{2}$ miles from Raubkammer held a large stock of chemical shell. The types held were :-

a. 7.5, 10.5 and 15 cm. charged :-

- Blue Ring 1
- Blue Ring 3
- Green Ring
- Yellow Ring
- Green ring yellow
- White Ring

b. 15 cm. Rockets charged :-

- Yellow Ring 1
- Green ring yellow
- Green ring 1

A complete inventory of the depot has been made by the British No.3 Chemical Defence Laboratory and reported elsewhere.

3. Aircraft bomb dump at Oerrel

At this depot about 3 miles from Raubkammer were held large stocks of 250 and 500 Kilogram bombs charged :-

- White Ring 1
- Yellow Ring 1
- Double Yellow Ring
- Blue Ring 2
- Green Ring 1
- Green Ring 2

An inventory of this depot has been made by the British No.3 Chemical Defence Laboratory and reported elsewhere.

4. Activities of WaF.

The following information was obtained from an informant of high rank concerning the department known as WaF.

The head of this department was Professor Schumann, who was well up in the Nazi organisation and maintained direct and close association with the head of the Waffenant. Schumann was also head of OKW/Wiss and acted as liaison link between OKW and the Reichforschungsrat. Wa.F. had the reputation of poaching interesting or important developments from the departments properly concerned, and was very unpopular amongst the latter. The number of fully qualified scientists employed was 40-50.

Among the problems worked on were :-

Development of hollow charge projectiles, especially for the Luftwaffe (informant stated that they had very good people on this work).

Use of chlorine trifluoride to produce an ultra-hot flame; to increase efficiency of fuel for ignition of flame barriers; in incendiary rockets. Wa.F. were responsible for recommending the building of the Falkenhagen plant, at a cost of 100,000,000 marks, for producing 50 tons per month of chlorine trifluoride.

Hydrolysis of mustard (comment by informant:- nothing new in this).

Production of stream of fire from aircraft.

Inhibition or destruction of I.C. engines (comment by informant - Gruppe X of Prüf 9 were more advanced in this subject)

Recoilless gun (in collaboration with Prüf 4)

Impulse shell.

Rockets with supersonic speeds (well equipped laboratories existed at Gatow near Kummersdorf for this work).

Atomic bomb.

Rays to inhibit I.C. engines.

Telephonic communication by light rays.

Development of ultra-red for seeing at night.

Penetration of and dispersal of fogs.

Improvement of penetration of mustard through skin.

Much of this work, specifically that on chlorine trifluoride, was characterized by informant (whose department was one of those suffering from the alleged poaching activities) as window-dressing.

5. Intelligence on Russia

The Russians were considered to have a mustard gas output of 5000-6000 tons per month, which could be doubled or trebled. The factories were begun in 1930 and finished in 1932; the sulphur dichloride process was used, and the product was not of high quality.

It was believed that the Russians have a one-stage process for making lewisite, but no further information could be given.

Russian shell containing DM, Clark I and CN were captured, as were training shell containing 10% solution of CN or mustard.

6. German Liaison with Russia

The use of an experimental ground at Tomka in Russia by a German mission in 1928 - 32 has already been referred to.

In the autumn of 1939 a party of 12 Soviet technicians visited Berlin to study German defensive equipment and methods of manufacturing it. Two of the visiting Russians were recognised as having been present during the Tomka trials. The Russians were interested in the following subjects :-

Manufacture of the respirator, especially from Buna (G.M.38)
Gasplane, including casein and montan wax papers, opponal and lyafol.
Defence against particulates.
Experience in impregnating and activating charcoal.
(Gas-Anzeiger).

The OKW ordered all information, constructional drawings and specifications on these subjects to be disclosed, and samples to be given as requested.

The party visited Draegers, Auer, Bata and Continental Gummiwerke (Cologne) and also an activated charcoal factory at Bremnitz.

The tour lasted eight days.

No questions were asked about offensive matters.

The Russians wanted to know why the chemical layer in the container had been given up and seemed suspicious when told that it was unnecessary. It became clear to the Germans later that the Russians had hydrocyanic acid in mind, but the former did not take up the point at that time.

The Russians were supplied with 50 G.M.38 containers and in return they later sent back some of their containers, which appeared to the Germans not to be from stock but to have been especially made up for the occasion. The HCN protection of these containers was, however, good.

The Germans believed the Russians to have 5000 to 6000 scientists and technicians, (excluding workmen and medicals) working on C.W. problems.

7. Liaison with axis countries

Liaison with Japan is dealt with in the body of the report.

Italian, Finnish, Hungarian and Rumanian delegations visited Raubkammer. Oberst Kowaliz was head of the Hungarian delegation, and General-Major Russo of the Italian. The Rumanians and Italians were not given much information, but the Finns and Hungarians were told a little more.

Investigation of Chemical Warfare Installations
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APPENDIX X.

A German Conception of the Principles of
Chemical Warfare Tactics.

- A. A tactical appreciation of the different war gases.
- B. Ground contamination.
- C. Use of Gas by the Army.
- D. Use of Gas by the Air Force.
- E. Ground decontamination.
- F. Use of smoke.
- G. The history, organization and equipment of the Nebeltruppe.

APPENDIX X.

A German Conception of the Principles of Chemical Warfare Tactics

The following is a translation of material supplied by Oberst Hirsch, Head of Wa Prüf 9, and constitutes a resume of the tactical use of German gas munitions as understood by him. Some of the information duplicates that included in other sections of the report, especially Appendix IV, but this has been allowed to remain for the sake of continuity.

A. A tactical appreciation of the different War Gases.

(a) White ring gases

Lachrymators are chiefly useful in order to bring about a paralysis of enemy activity. They are very economical in use as quite small concentrations are ample to necessitate the wearing of a respirator. They are mainly used for surprise attacks. If necessary the effect, which is often of short duration, can be made to persist for longer periods by the intermittent firing of white ring shell.

By the use of air burst bombs large areas of ground can be covered in such a manner as to make them quite uninhabitable without a respirator. In warm weather woods can be made unapproachable for weeks without a respirator. These bombs are particularly suitable for employment against prepared positions, reserve depots, lines of communication, and supply depots. A good effect is obtained for a short time by spraying CNS solution from low flying aircraft. In very high concentrations the white ring gases also effect a considerable skin irritation.

Closed rooms can be contaminated with white ring gases in such a manner as to make them continuously uninhabitable and for this purpose portable spraying apparatus, hand grenades and glass containers are suitable. White ring substances can also be emitted in good yield from thermal generators so as to be effective to a considerable depth. As only small concentrations are required it is possible to keep up the attack day after day on heavily defended points with thermal generators.

(b) Blue ring gases.

Blue ring gases can be used in much the same way as white ring gases, but their effect is only noticeable after a delay of a few minutes. On account of this they are best employed in the form of H.E./Chem. shell. Such shell would behave like normal H.E. shell and would not be recognised as chemical shell so that it might be possible by means of a sudden attack to surprise the enemy without his respirator. By the time the enemy has recognised the presence of the blue ring gas and has put on his respirator it is already too late and the full effect of the blue ring gas then becomes noticeable.

As the modern filter is so effective it is hardly to be expected that blue ring gases could be made to penetrate the respirator. Examination of captured English filter-containers, however, has shown that their protection against field concentrations of particulates is in many cases inferior. Against such an imperfect protection it would be simple to achieve penetration particularly by means of thermal generators.

Thermal generators evolve blue ring gases in good yield and even on a narrow front can achieve effects to a depth of 80 kilometres. Continuous use of thermal generators day after day would lead to the complete exhaustion and incapacitation of troops forced to wear their respirators.

Excelsior is considered to be the most effective of the blue ring gases. It is suitable for filling into small calibre ammunition which is highly efficacious.

The simultaneous use of blue ring and green ring ammunition is hardly likely to be successful under modern conditions.

Blue ring gases are also suitable for charging into hand and rifle grenades. These can be used advantageously against machine gun nests and anti-tank guns.

(c) Green ring gases.

The employment of green ring gases should be left chiefly to the Air Force according to German opinion. The green ring gas artillery shoot has lost its significance, but salvo shoots by large calibre projectors appears to be a promising form of attack.

Here again an endeavour should be made to surprise the enemy. The so-called "Dauerschieszen" (continuous fire) of the last World war seems unlikely to achieve any worth while results against the modern respirator container.

In addition to the use of large aircraft bombs the spraying of green ring gases from low flying aircraft appears to be a very promising method. Against personnel one might expect to achieve complete annihilation by means of a surprise attack. For use in a surprise attack, the gas should, if possible, be effective in small concentrations, so that there is a possibility of effecting casualties before the respirator can be adjusted. This conception has lead to the development in Germany of a new class of war gases - Tabun and Sarin. With both these gases, but especially with Sarin, a surprise attack might be expected to lead to a high percentage of serious casualties.

According to German ideas it is unnecessary to strive after a definitely lethal concentration. It is much better to make the enemy temporarily unfit for military duties.

As the bulk of the green ring gases are lachrymatory or at least possess a noticeable smell it is extremely difficult to surprise the enemy with them. It was on account of this that nitrogen mustard, which is very difficult to detect, was charged as a green ring gas into H.E-Chem. shell in Germany. The search for an effective green ring gas without smell or irritation has so far been in vain.

(d) Yellow ring gases.

Here there is little change from the well known employment of these gases in the last world war. The manufacture of thickened mustard has produced an increased persistence of ground contamination. The mixture of ground contaminants with supplementary agents has also increased the persistence and lowered the F.P. (so called Winter lost).

A new method of laying ground contamination by means of aircraft is important. Low spray is especially effective against personnel. Medium and high sprays seem to be possible technically, but are tactically of little importance on account of the difficulty in aiming the spray.

For carrying out ground contamination there are now also bulk contamination vehicles, spraying mines, and glass bulbs filled with gas.

The dispersal of gases normally used for ground contamination from thermal generators is also possible when these gases become highly effective green ring gases.

Nitrogen mustard, thickened mustard, and mixtures of mustard with oils are particularly difficult to decontaminate.

Lewisite is considered an unsatisfactory ground contaminant on account of its lachrymatory properties, its strong smell and the ease with which it can be decontaminated.

(e) Nettle gases

War gases which have an immediate effect on the skin (e.g. Phosgene oxime) are considered to be very effective. They are particularly suitable for low anti-personnel spray and can achieve surprisingly good results by this method. The question of the stabilisation of phosgene oxime does not seem to have been solved anywhere, however.

The spraying of concentrated acids is much less effective.

B. Ground Contamination

Fortifications constructed by pioneers and chemical barriers can both be used for the technical strengthening of areas which have been selected for defence. Chemical barriers can also be used alone when this fits in with the intentions of the Higher Command. The laying of every chemical barrier must have the approval of a Higher Commander (usually an Army Commander) and must fit in with the general defence plan.

It must be realised as fundamental to the laying of such a chemical barrier that it must be under the protection of ones own fire. A chemical barrier which is not so protected is too easily penetrated by the enemy without heavy casualties and is also too easily decontaminated. Ones own defensive fire should be used to force the enemy to the ground and bring him into considerable contact with the contaminated surface. The longer and oftener the enemy is forced to the ground the more casualties he will suffer.

Chemical barriers can be used for many purposes. They can either be used as definite obstacles to an advance or in order to guide an expected attack in a desired direction particularly favourable to the defence. In addition to this they may enable defensive troops to be spared for other purposes.

Every barrier should be tactically as effective as possible. When constructing the barriers it is best to make a reconnaissance of the most important positions for contamination from the enemy side in order to be able to contaminate more or less heavily according to the importance of the area. Positions which are absolutely vital to the enemy for his attack should be particularly heavily contaminated.

For ground contamination a distinction is drawn between a "harassing" contamination and a "barrier" of contamination. Harassing contaminations are limited areas of contamination at specially important points not connected with one another e.g. cross-roads, cuttings, roads leading to or from bridges, important observation posts etc. Barrier contaminations are large areas of contamination more or less connected with one another and set at right angles to the line of advance of the enemy.

The normal degree of contamination for both types is about 100 g/m^2 , but this figure can be doubled where the ground is unsuitable or the weather unfavourable.

Barriers of contamination may consist of points of contamination or areas of contamination. Point contamination is a regular chess-board arrangement of contaminated areas of small diameter constructed in sufficient depth to prevent the enemy from being able to pass through without coming in contact with the gas. Area contamination is made up of large areas of contamination joined together to form one or more defensive belts. The minimum depth for any one belt is that depth which the attacking troops cannot cover in one rush. Normally the least depth for one belt is at least 50 metres. The distance apart of the various belts depends on the nature of the ground and the tactical situation. According to the latest Russian reports a barrier should be laid at least 1 kilometre deep along a front at least 15 kilometres wide, so that it cannot easily be by-passed. Such an extensive barrier requires an enormous amount of gas, however.

Ground contamination can be laid by

- (a) Bulk contamination vehicles.
- (b) Sprühh buchsen (spraying mines).
- (c) Improvised means.
- (d) Boden kugeln (glass bulbs charged gas)
- (e) Artillery fire.
- (f) Aircraft bombs.
- (g) Low spray (to give slight persistence)

(a) By means of vehicles specially constructed for this purpose war gases can be distributed in quite a short time as a most economical and effective manner. If the vehicles are suitable for cross country work, then difficult country can also be contaminated. The medium sized bulk contamination vehicle used by the Nebeltruppe can cover a belt 700 m long by 22 metres wide with a contamination of 100 g/m². In order to calculate the necessary speed a "spray table" was prepared.

(b) Ground contamination by means of spraying mines is prepared by burying the mines or even by just setting them on the ground in a chess-board pattern so that they are 15 metres apart in all directions. The ignition of the spraying mines is effected by means of either a time fuse with a 3 minute delay, a safety fuse of chosen length, an electric fuse to set off groups of 50 to 100, or fuses which are actually by the enemy himself by means of trip wires etc. This last method has the advantage that the whole body is likely to become contaminated from the falling drops.

The chief advantage in the use of spraying mines for laying ground contamination is that the contamination can be laid at the last minute and the enemy encounters a fresh and very active contamination.

Spraying mines can also be used for closing gaps in belts of contamination laid by the bulk contamination vehicles. They can also be used in conjunction with tank barriers to become effective when the barriers are being removed.

Spraying mines can also be laid by motor transport. The mines are fitted with a spike on the bottom end which penetrates the ground and keeps the mine upright when it is set in its place in this manner. If the 3 minute delay fuse is used then the speed of the vehicle must be at least 4 km. per hour.

Spraying mines which are set in the ground at an angle can be fired a distance of about 200 metres and salvos of up to 100 can be fired in this way by electrical ignition.

- (c) For improvised methods of ground contamination various utensils can be used e.g. watering cans, agricultural vehicles for spreading liquid manure, and in fact almost any vehicle to which a tank and a spray has been fitted. Any tin can may be converted into a spraying mine by placing a charge under it so that it will contaminate a circle of 15 to 20 metres diameter.

- (d) The purpose of laying ground contamination in the form of Bodenkugeln is to preserve the gas from the effects of the weather until it becomes effective through the action of the enemy himself. They are broken by the preliminary bombardment of the enemy or when an enemy presses on one with his full weight. In the latter case the enemy should be forced to the ground by fire.

The Bodenkugeln are spread well-concealed and chess-board wise over the ground in such a manner that there is at least one but better still two or three per square metre. In long grass etc. any further concealment is usually unnecessary.

Bodenkugeln can also be thrown so as to contaminate inside rooms or vertical surfaces.

- (e) Ground contamination through the firing of yellow ring shell is dealt with in Section C. The advantage of laying contamination by means of artillery shell is chiefly that the contamination is spread in country which is already occupied by the enemy and therefore produces high rates of casualties. The disadvantage is the big expense of ammunition and the demand on the large number of guns which are required for a large area of contamination. When once a barrier has been laid, however, the contamination can be continually freshened up and kept active by means of intermittent fire. The actual craters remain active for a long time.

The following can be taken as a good indication of the ammunition requirements for ground contamination per hectare:- 25 shells from 10 cm light field artillery and about $\frac{1}{3}$ of that for heavy field artillery. When projectors are used for ground contamination the ammunition requirements depend very much on the scatter of the weapon used.

(f) Ground contamination is more difficult to lay with aircraft bombs than by any of the other methods mentioned in (a) to (e). The use of yellow ring bombs with DA fuses is not advisable for this purpose. The 250 kg bomb is too big and uneconomical, but the 50 kg bomb can be used with much better effect. The bombs must be dropped in sticks so that there is a broad overlap between the various areas of contamination. The contamination is most irregular in that it is too light on the outside edge of the area and far too heavy in the centre. The bombs also require to be dropped in such a manner that no clean path can be found through the area of contamination. If an extensive area is to be covered the large requirement in ammunition and aircraft makes the use of the DA bomb inadvisable. On the other hand this method is ideal for the contamination of important targets or for anti-personnel attack.

Far better and above all far more economical is the use of the air burst bomb charged with thickened mustard. According to wind-speed and height of burst a 250 kg bomb will contaminate an area 200-600 metres long by 50-200 metres wide. The normal contamination with thickened mustard may be taken to be 10 g/m^2 . Due to the greater persistence of thickened mustard such a contamination can be expected to last under suitable weather conditions for 6-8 days.

This type of contamination is also most suitable for increasing the effect of H.E. bombs. The enemy finds the clearing up much more difficult and dangerous.

Trials to lay ground contamination by means of clusters of Bodenkugeln did not prove successful.

(g) Long narrow belts of light contamination can be laid by means of low spray. A contamination of $10\text{-}20 \text{ g/m}^2$ covers a width of 20-25 metres and this should remain effective for about 12 hours. If greater persistence is required or a greater width of contamination then several aircraft can be used at once. Low spray is particularly effective against personnel.

Narrow belts of contamination can be laid very quickly by this means. Russian instructions stress the importance of using this method to slow down and halt an enemy in close pursuit.

C. Use of Gas by the Army

General

The value of firing gas ammunition in place of H.E. lies in the fact that the effect covers a far greater area than that achieved by the H.E. The length of time for which it remains effective is also far greater than for normal ammunition.

On account of the high standard of gas defence of the modern army only the use of gas in large quantities is likely to achieve any success. The direction of the gas war is the task of the Higher Command. Decisive for success is the element of surprise. This must be attempted at all costs.

Any gas attack is dependent on the ground and weather conditions. A well organised meteorological service is therefore the foundation for the conduct of a gas war.

1. Types of gas attack

The following different tactical attacks are differentiated as under:-

(i) Surprise Attack (Der Gasüberfall)

Consists of an attack on a definite objective for a definite space of time with as many pieces as possible and with the highest rate of fire. The duration of the shoot is at the most 2 minutes. The purpose of the attack is to annihilate the enemy before he can put on his defensive equipment. At least the enemy should be so badly attacked that he is unable to continue fighting even if most have succeeded in adjusting their respirators.

(ii) Crippling fire. (Lähmungsschiessen)

Usually commences with a surprise attack to be followed up over a longer period by the use of smaller quantities of ammunition. The purpose is to force the enemy into his respirator and to keep him there so that he is incapable of putting up a normal defence.

(iii) Harassing fire. (Das Ermüdungsschiessen).

Consists of firing sufficient ammunition per hour, if necessary for days on end, to force the enemy to wear his

respirator continuously. The purpose of this is to wear down the enemy by forcing him to wear his respirator for long periods.

(iv) Contamination shoot

The purpose is to contaminate the ground and especially gun positions with persistent gas so as to make it impossible or at least very difficult for the enemy to use the ground.

(v) Use of Gas in an H.E. shoot

The purpose is to disquiet the enemy and force him to constant gas preparedness.

2. Chemical Ammunition

(i) Artillery Ammunition

As it was a military necessity that the storage and supply of ammunition should be kept as simple as possible this forced a limitation to only 3 special types of gas shell. As a fourth type the normal H.E. shell can be used for several chemical chargings.

The allocation of these 4 types of shell to the different chemical chargings was made from the following point of view.

- (a) Solid Chemical Chargings. These are filled into the normal H.E. shell. The fragmentation is about 80 per cent of the pure H.E. shell and the detonation is difficult to distinguish from that of the H.E. shell.
- (b) Liquid Chemical Chargings. The "head burster shell" (Zwischenboden geschoss) is used for gases for ground contamination, for volatile gases and for non-persistent gases which are thermally unstable. On account of its small explosive charge, weak detonation and small fragmentation effect it is recognised to be solely a gas shell.

The shell with a wide burster container has been developed for the use of the less volatile and thermally stable gases. On account of its strong explosive charge this can be looked upon as an H.E.-Chem. shell with a strong fragmentation effect which can hardly be distinguished from an ordinary H.E. shell by the sound of the explosion.

- (c) Chemical thermal generators. For these the shells with the ejection pots were introduced. The shells carry the thermal-chemical mixture in special pots which are thrown out and ignited in the air over the target and continue to burn on the ground. This is purely a chemical shell without any H.E. effect.

(ii) Projector Ammunition

By leaving out the head-burster and pot-ejection types of ammunition it was possible to have only 2 different types of projectile.

- (a) Solid chemical Chargings. For army use the ordinary H.E. projectiles were to be used and the chemical introduced in a tube into a hole in the centre of the explosive. The projectiles have both strong blast and fragmentation effect.
- (b) Liquid Chemical Chargings. For volatile or heat sensitive chargings a projectile with a small burster container is used. These projectiles have only a small H.E. effect.

For less volatile chargings and those stable to heat, projectiles with a wide burster container are used. The large explosive charge makes these H.E.-Chem. projectiles.

3. Expenditure of Ammunition.

- (i) Non-persistent gases. (Including initial cloud).

The standard for the expenditure of ammunition is the hectare, for short haE. This is understood as being the quantity of ammunition required to be shot on to one hectare in one minute in a 5 metre/second wind in order to achieve a concentration of about 100 mg/m^3 . This amount is sufficient to cause heavy casualties to the enemy. If the effects are required to be fatal then the amount employed should be that which gives the Ct for $t = 1$.

- (ii) Persistent gases.

Again the standard in the hectare - haE. Here is understood the expenditure required in order to achieve a contamination of 10 g/m^2 . The hectare standards for gas clouds and persistent gases are shown in the following two tables.

Hectare standard for Gas clouds

<u>Type of Ammunition</u>	<u>Expenditure reqd. per haE.</u>
F.H. Gr.	60
10 cm. K. Gr.	60
15 cm. H. Gr.	20
15 cm. K. Gr.	20
15 cm. I. Gr.	20
15 cm. Wgr. 41.	144 (This quantity is for 16 hectares, the smallest area which can be considered due to the large scatter of the weapon).
30 cm. Wk.	Not yet determined.

The numbers in this table apply only to green ring ammunition, for white and blue ring ammunition, where only harassment is to be produced, only a fraction of the above expenditure is necessary and this varies according to the weather and the nature of the country.

Hectare standard for Persistent Gases

<u>Type of Ammunition</u>	<u>Expenditure reqd. per haE.</u>
F.H. Gr.	150
10 cm. K. Gr.	150
15 cm. H. Gr.	50
15 cm. K. Gr.	50
15 cm. Wgr. 41.	800 (This quantity is for the contamination of 16 hectares as this is the smallest area which can be considered due to the large scatter of the weapon).

The figures in both the above tables refer to a length zone of 100 metres. Where the length zone is 100-200 metres the figures require to be doubled and for length zones over 200 metres trebled.

3. Marking of Gas Ammunition

(i) Basic principles

Chemical shell are identified by coloured rings on the ogive and on the base. Chemicals which have a similar effect are given rings of the same colour. As far as it is necessary from tactical considerations different chemicals which have the same effect are differentiated by means of arabic numerals placed below or within the rings. e.g. Green ring 1, Green ring 2, etc. A number of rings indicates an increase in persistence, e.g. double yellow ring.

(ii) Types of Ammunition

- (a) Shell, Green ring yellow. Shell with a wide burster container : charging - mustard. H.E.-Chem. The narrow yellow ring is there to indicate that leaks might cause injury to the skin on handling.
- (b) Shell, Green ring 1. Shell with wide burster container : charging - nitrogen - mustard. These shell should not be shot mixed with others as otherwise their chief advantage, the fact that the charging is difficult to detect, would be lost. H.E.-Chem. shell.
- (c) Shell, Green ring 2. Shell with burster container : charging - phosgene. Only 30 cm. projectile planned.
- (d) Shell, Green ring 3. Shell with H.E. filling in head. Charging - Tabun. Shell without strong fragmentation effect.
- (e) Shell, Green ring 4. Shell with wide burster container. Charging - Sarin. H.E.-Chem shell.
- (f) Shell, Green ring 5. Shell with burster container. Charging HCN. Only planned for the 30 cm projectile.
- (g) Shell, Yellow ring. Shell with H.E. head filling. Charging - Winter lost. Shell without strong fragmentation effect.
- (h) Shell, double yellow ring. Shell with H.E. head filling. Charging - thickened mustard. Shell without strong fragmentation effect.

- (i) Shell, blue ring 1. Normal H.E. shell. Charging DM or DM/DA mixture. H.E.-Chem. shell.
- (k) Shell, blue ring 2. Shell with wide burster container. Charging DA in Arsinol. H.E.-Chem. shell.
- (l) Shell, blue ring 3. With ejection pot. Charging A Powder with DM. Pure gas shell, no fragmentation effect.
- (m) Shell, White ring. Normal H.E. shell. Charging - CN. H.E.-Chem. shell.

D. Use of Gas by the Air Force

O.K.W. ordered, that should gas warfare commence, the main effort in the offensive use of gas should be made by the Air Force. As a result of this all possible methods were studied and developed and the necessary apparatus was either already stored in large quantities or was being manufactured.

Two possible offensive methods are available:

- (a) dropping of chemical bombs,
- (b) spraying of chemicals from the air.

- (a) The dropping of bombs in level flight is possible from all heights and in addition to this bombs can be dropped with great accuracy by dive bombing. All kinds of non-persistent as well as persistent gases can be employed in bombs. According to the type of fuse a distinction is drawn between direct action bombs and air-burst bombs.

White ring aircraft bombs can be prepared in various ways. The following have been tried out and to a certain extent introduced into the Service.

- (1) White ring bomb with CN filling and airburst. Effective area, 200-600 metres long and 100-250 metres wide according to the height of burst. The persistence of the lachrymatory effect is about 3-4 months in warm weather. The employment of such bombs against reserve troops and prepared positions in woods is particularly effective. Woods can be made quite unapproachable without a respirator.

- (2) White ring bomb with a filling of CNS solution and a direct action fuse. Effect same as for (1) over an area 50-60 metres in diameter and 200 metres downwind of this. Persistence in summer is about 2 days.
- (3) White ring thermal generator bomb with a charging of CW thermal mixture and direct action fuse. The bomb penetrates up to one to three metres into the earth, according to type of ground, and begins to generate after 2-3 minutes. Such bombs can be effective for a considerable distance downwind and when a large number are used can cause lachrymation to a depth of 30-50 km. To be used effectively the bombs should be dropped well up-wind of the target. A stick of 8 x 50 kg bombs is sufficient for a target width of about 300 metres.
- (4) Clusters of white ring thermal generators (21, 72 or 120 according to size of cluster) which open in the air and distribute the generators over an area of 80-150 metres long by 50-80 metres broad. The generator is ignited by means of an allways direct action fuse which becomeslive when a safety pin is unscrewed by a tail diving flight. On account of the high concentration the effect from the relatively small scatter zone is good. It was intended to employ this cluster against anti-aircraft positions etc.

Blue ring gases are used in thermal generator type bombs. Quite recently attempts had been made to develop a fragmentation bomb with a blue ring gas or CN added and the trials had shown considerable promise.

The 50 kg blue ring thermal generator bomb had an emission time of 3-5 minutes and was effective to a depth of several kilometres. Usually dropped in sticks 30 metres apart the effective depth of a stick of 8 bombs was anything up to 10 kms in suitable weather conditions.

The cluster mentioned in (4) above was also being considered for blue ring thermal generator type bombs.

For the war head of the apparatus BO 24 (V1) a charging of 200 blue ring thermal generators was to be provided. The emission time of one generator was 1-1 $\frac{1}{2}$ minutes.

Blue ring bombs and blue ring clusters were to be used chiefly for the attack of AA guns, battery positions etc. Fragmentation bombs with the addition of blue ring gas were to be used against personnel, marching columns of men, defensive positions etc.

Yellow ring gases were only to be used in bombs. Two types of bombs were introduced. A 250 kg. bomb with a direct action fuse was to be used chiefly for ground contamination. The contaminated area is elliptical in shape and roughly 70 metres long by 50 metres wide. The persistence in summer is about 1-2 days and in the crater 3 days. The bombs should be dropped in parallel rows so that the areas of contamination overlap and no uncontaminated pathways through the area are left. To put down an extensive barrier of contamination a large expenditure of bombs is necessary.

A yellow ring air-burst bomb with a charging of thickened mustard was introduced as the KC 250 II Gb. The area of contamination varies according to the height of burst and the wind speed. On the average contamination with a persistence of 24 hours could be produced over an area 300-350 metres long by 80-200 metres wide. These bombs are also suitable for the subsequent contamination of targets which have already been attacked with H.E.

Trials with clusters of 1 to $1\frac{1}{2}$ kg. mustard bombs did not prove this method to possess any advantage and a trial of the 'Bodenkugeln' in a cluster was shown to be impractical as many of the bulbs either broke in the air or fell unbroken on soft ground and at any rate they did not produce a sufficiently continuous contamination.

Green ring gases are only charged into bombs with DA fuses. Only bombs with phosgene charging have been introduced viz. 250, 500, 100 and 1800 kg.

Trials with a Tabun charging in the 250 kg. bomb were not successful. On the other hand preliminary trials with a cluster of small Tabun bombs were most promising and gave far better results than those obtained with the larger bomb. It was expected that only clusters would be used for Tabun and Sarin chargings.

The use of HCN in bombs proved most difficult as the charging inflamed on detonation. Trials to overcome this difficulty by the addition of CNCl or water to the charging showed little improvement.

The employment of a nitrogen-mustard bomb, with a large bursting charge would have been feasible but such a bomb was not provisioned.

Green ring bombs with volatile chargings are very effective especially when using the bigger bombs which can produce a lethal area of up to 10,000 m² and a casualty area two or three times as big. The effective depth from a single bomb or a stick is small, but from a mass attack is very considerable. Green ring bombs are particularly suitable for attacking heavily populated areas. The persistence in built up areas may amount to as much as several hours according to wind and weather conditions.

- (b) The spraying of gas from spray apparatus, which is fitted into the aircraft or is carried under wings, is particularly effective from low altitudes. The persistent gases are most suitable for spraying, but non-persistent gases (perstoff, phosgene HCN) can also be sprayed from suitable apparatus at heights not above 50 metres.

With apparatus such as the S200 and S300, which are approved stores, a spray concentration is obtained which is easily sufficient for anti-personnel attack. The effective area of contamination for one apparatus depends on the height of the aircraft and the wind speed and direction. In general a long narrow band of contamination is produced about 400-600 metres long and 20 to 80 metres wide. In the middle portion (so called "Kernzone") of this band contaminations of 15 to 40g/m² were measured. The mid-portions are effective as barriers of contamination and remain effective for 1 to 1½ days. For anti-personnel attack the whole of the band is effective except for the very smallest drops on the downwind side.

Spray is chiefly employed against marching columns of troops, defense zones, gun positions and any collection of men or animals.

Medium or high spray is quite possible with thickened material, but it is very difficult to aim the spray on to a target. The German opinion is that this technique is only suitable for the attack of very large areas which are well populated.

The spraying of non-persistent gases was specially developed by the Russians and appears to be an extremely effective form of attack. It is important, however, that the outlet is

sufficiently large, so that the gas can escape in a very short space of time (2-4 seconds according to the speed of the aircraft). The aircraft should not fly at over 25 metres.

By means of the S500 (an altered Russian WAP 500) HCN concentrations of up to 20 g/m^3 were obtained. Two S500's charged phosgene gave concentrations of $30\text{-}40 \text{ g/m}^3$. Such concentrations are lethal instantly for unprotected men and animals.

The introduction of such a technique at the vital point of a battle could be expected to have a decisive effect.

As well as volatile green ring gases a lachrymator, CNS solution can also be sprayed. The S200 and S300 can be used for this solution and the aircraft can fly at up to 100 metres. The lachrymatory effect lasts in summer for about half a day and forces everyone to wear a respirator. In Germany it is also considered that a solution of phosgene oxime would be an excellent material for such attacks.

The Russians had a great partiality for low spray attacks with liquid incendiary, but these proved to have little effect apart from the initial effect on moral.

E. Ground Decontamination.

Extensive chemical barriers, which cannot be penetrated via clean areas and which cannot be by-passed, must be cleared by mechanical or chemical means. This is difficult to carry out if the contamination barrier is guarded by a sufficient cover of fire. Ground decontamination is the duty of the decontamination battery of the Nebeltruppe as well as the Pioneers if it is to be done by mechanical means.

The removal of a chemical barrier by mechanical means can be accomplished as follows:-

- (a) By scraping off the upper surface to a depth of about 10 cm.
- (b) By making gas free trenches or furrows with the decontamination plough or improvised agricultural ploughs.

- (c) By covering the contaminated surface with clean earth, hay, straw, brushwood etc. to a depth of 15-20 cm.
- (d) By bridging the contaminated surface with boards, tiles a yard apart, rolls of roofing material, the service "Gas läufer". (A 50 metre long roll of gas plane paper impregnated with Montan wax) mats woven out of straw (quoted from a Russian directive) gas planes a jump apart.
- (e) By burning the surface contamination with hay or straw which has been soaked in paraffin or petrol (according to Russian directions 1 kg of unflammable material soaked in 500 g. oil should be used per sq. metre.
- (f) By washing down; hosing with plenty of water without the addition of any decontaminant where the surface is suitable. (e.g. cobble or asphalt streets or roads).

The decontamination of the ground by chemical means can be carried out with either solid or liquid decontaminants. As solid material bleach or an improved bleach called Losantin can be used. Liquid decontaminants are chlorine water, bleach water and solutions of other substances containing chlorine. In Russia sulphuryl chloride dissolved in ethylene chloride is used. In general on account of the military transport problems solid materials are preferred to liquid.

The dispersion of the decontaminant is carried out by means of cross-country spreaders or sprayers according as to whether a solid or liquid decontaminant is being used. The medium sized motor decontamination truck of the German decontamination battery can cover a strip 700 metres long by 2 metres wide with 500 g/m² of Losantin with one filling.

The usual quantity of decontaminant to be used for medium contamination (up to 200 g/m² mustard) is 500 g/m². For heavier mustard contamination or for nitrogen mustard 1 kg/m² should be used. In the case of nitrogen mustard the time allowed between decontamination and traversing should be increased by a factor of 3. Normally when mustard has been decontaminated by Losantin this is 20-30 minutes. The requirements for decontamination material and the time allowed for decontamination must also be increased for thickened mustard and mixtures of mustard and oil.

As can be seen from the above the requirements on decontamination material is relatively large. So as not to overburden the supply services only limited use can be made of decontamination. It is impossible to try to decontaminate large areas. In most cases one would have to confine oneself to the decontamination of narrow paths through the wide barriers or to the decontamination of small, but tactically important points (M.G. positions, gun positions, important observation posts). The weather would be left to carry out the decontamination of unimportant areas.

The crossing of a chemical barrier can be compared tactically to the crossing of a river. It is necessary to form a bridge-head on the enemy side of the contamination so that under its protection the decontamination of the necessary number of paths can be begun. With the increased use of M.T. mechanically laid barriers appear to have lost a great deal of their importance. Motor vehicles are in just as much danger as infantry, however, when penetrating a barrier of spraying mines.

Sufficiently strong bodies of assault troops in light gas clothing are sent into the attack through the contamination in order to give a defensive covering fire. In order to equip these troops with light gas clothing each decontamination battery carries 1200 sets of light gas clothing. Narrower barriers can be crossed by means of spread out gas planes or with improvised body protection.

It is obvious that an exact reconnaissance of the extent, concentration and age of the chemical barrier should first be carried out. This reconnaissance is made by the gas scouts of the troops or by the motorised gas scouts of the decontamination battery. Their function is to determine the exact position of the nearest edge of the contamination, the type of gas used and the strength and age of the contamination: then the position of the various bands of contamination must be determined and finally the edge of the contamination on the enemy side and all these marked in an unmistakable manner with gas flags. Detector powder is used to establish the presence of gas contamination and this is helped out if necessary by the use of the "Gasanzeiger". Where possible areas free of contamination or only slightly contaminated should be used for the formation of clean paths. When the reconnaissance is finished the decontamination vehicles proceed with the construction of the paths. In general 3 to 5 paths are made per company sector and one of these must be 2 metres wide for vehicles. When making the paths advantage should be taken of all available cover. When the necessary time has been allowed for the decontamination to take effect then the attacking troops begin to march over the clean paths and fan out to continue the attack on reaching the other side.

Special road decontamination batteries with their own improvised spreaders are provided for the decontamination of roads and tracks at the front and behind the front lines.

For the cleansing of contaminated personnel and for the decontamination of their weapons, equipment and uniforms the troop decontamination companies are provided with special vehicles (cleansing vehicle, bath-vehicle, water-vehicle, decontamination of clothing vehicle etc.) and the decontamination battery with auxiliary vehicles. Fifty men can be completely cleansed within 20 minutes by means of the auxiliary bath equipment, with the special cleansing vehicles 120 men in 30 minutes. The decontamination of the uniforms takes about 12 hours and the boots also about 12 hours and a number of improvised methods have also been introduced for this purpose. The decontamination of weapons is carried out by the soldier himself by means of the weapon decontaminant introduced for that purpose. Larger weapons or pieces of equipment are treated by the decontamination battery or by the decontamination troops of the battalion and regiment.

For skin decontamination, which is carried out by every soldier himself during the battle, each man possesses a package of skin decontaminant (Losantin tablets) or a jar of skin decontamination ointment.

The decontamination of towns and works behind the lines is a matter for the civilian A.R.P. For this are available the well-known decontamination materials as well as the local organisations for road decontamination. The decontamination of clothing should be carried out in the local laundries and chemical cleaning plants. The decontamination of railway installations should be carried out by specially trained railway personnel with improvised equipment.

The ground staff of the Air Force also possess decontamination squads who have been specially trained to decontaminate aircraft and leaking ammunition.

The Navy had on board each ship special decontamination squads who carried out decontamination mainly with the help of steam.

F. The Use of Smoke

In the instructions for the German Army there were it is true abundant orders as to the use of smoke in attack and defence, but in actual practice the use of smoke was generally unpopular and seldom used. Only in the last stages of the war did the copious use of smoke by the Allies appear to evoke the High Command and the

Forces to lose their aversion to it so that here and there a more active use of smoke appeared.

Tactically a distinction was made between "camouflage smoke" (Tarnnebel) and "screening smoke" (Blendnebel). By screening is understood the laying of a smoke screen immediately in front or on top of an enemy position. By camouflage smoke is understood the covering of ones own positions or movements by means of smoke. The nearer a smoke screen is laid to the enemy the more economical is the amount of smoke required to produce an effective screen.

The training of troops in correct use of smoke materials and to a correct appreciation of the meteorological factors is not easy. The extensive use of smoke should only be carried out by order of the Higher Command. (Army Corps, Army). The tactical use of smoke on a small scale is carried out by orders from Division, Regiment, Battallion or Company Headquarters. Fighting in smoke is similar in many respects to the conditions in night fighting. This also explains the aversion of the Higher Command and of the troops to the extensive use of smoke.

The following smoke ammunition and apparatus have been developed and in most cases also accepted into the Service.

- (a) Smoke hand grenades (burster and generator types).
- (b) Rifle grenades (burster and generator types).
- (c) Smoke bombs for the attack of tanks.
- (d) Smoke generator (emission time - 3 minutes).
- (e) Quick Smoke generator (emission time about 1 minute).
- (f) Long Smoke generator (emission time about 20 minutes).
- (g) Long smoke generator, black (black smoke).
- (h) Smoke projectiles for all guns and projectors.
- (i) Smoke spraying apparatus with emission time of 30 - 120 minutes.
- (j) 50 kg. Smoke bomb (NC-50, emission time 15 - 20 minutes).
- (k) Clusters with 20 to 72 smoke generators.
- (l) Aircraft smoke curtain installations.

- (m) 250 kg. Smoke bomb (charging CSA (Nebelsaure)).
- (n) Smoke floats and smoke buoys for Navy and Pioneers.
- (o) Wireless controlled smoke carrier (Goliath).

The troops were very well supplied with smoke materials. The monthly supply was far greater than the amount used so that a large stock of smoke material was built up.

The principles for the tactical use of smoke were applied in exactly the same manner as in other armies. The chief use of smoke was by the firing of smoke ammunition and from the Air Force. The commonest use of smoke was for the screening of river crossing. A further important use of smoke was the area screening of factories and towns. For this purpose the Air Force had set up local formations who carried out smoke screening corresponding to the local wind conditions with the help of smoke spray apparatus. For the protection of specially important smaller installations such as lock gates, dams and U-boat shelters a smoke spray apparatus was recently developed which formed a smoke cloud up to 50 metres high in 2 to 3 seconds. It consisted of a pressure vessel with three exit tubes in an upward direction and the pressure was derived from the gases from an electrically ignited black powder filling.

The Navy made considerable use of smoke during their various naval engagements and also to screen ships lying in harbour.

The increasing use of smoke by the Allies on the South and West fronts caused the original aversion to the use of smoke to become less noticeable in recent times. If the war had continued the German Armed Forces would also have made much greater use of smoke. The complete lack of phosphorus which (also in German opinion) is the best source of smoke and has, as well, a considerable effect on moral was a disadvantage.

G. The History, Organisation and Equipment of the Nebeltruppe.

There was no Nebeltruppe in the German 100,000 man army in the first few years after the world war. Smoke screening was carried out at manoeuvres by the pioneers or infantry with improvised means. Experience gained by the civilian A.R.P. from the screening of large industrial areas, was passed on to the troops without any special directions being laid down or any special body of troops formed.

1932.

In Königsbrück (near Dresden) a Nebel squadron was formed. It was equipped with smoke spray apparatus (portable and mounted) and also with smoke generators.

1934.

This squadron was converted to the Nebel Battery (Abteilung) Königsbrück. The equipment remained the same, but was considerably increased and the battery became motorised.

1935.

This was the year of the birth of the Nebeltruppe. Inspektion 9 was set up and also an Inspektion der Nebeltruppe. The Truppe itself was composed only of the Nebel Battery, Königsbrück, with one instructional company detached from it.

1936.

The Nebeltruppe was increased in size to two batteries which were equipped with the 10 cm. Nebelwerfer 35, introduced to the Service in 1935. Each battery consisted of three troops and each troop had two sections of four Werfer. The Nebelwerfer 35 has a maximum range of 3500 m. The highest rate of fire for a short time is 15 rounds per minute. Mortar bombs were earlier filled with a mixture of sulphurtrioxide and pumice, and later only with sulphurtrioxide. The results were excellent in humid weather conditions, and in dry weather were still sufficiently good. This ammunition was still being used during the French campaign. The first battery remained in Königsbrück and the second was formed in Bremen.

1937.

In October an instructional Nebel battery was formed with a third battery at Celle.

1938.

In this year two further batteries were formed. The fourth at Munsingen and the fifth in the west near Kaiserslautern. Up to this time the Nebelwerfer batteries as well as being equipped with eight projectors per battery, also had a decontamination and bulk contamination vehicle so that they could be used as smoke troops, decontamination troops or gas contamination troops as required. They were trained in all three. Each battery had the following composition.

Staff
 Signal Troops
 1-3 troops.
 Light Column. (supply of ammunition for projectors).
 Heavy Column. (composed of all decontamination and bulk contamination vehicles as well as vehicles for the transport of decontamination material and gas containers).

This set up was shown in the big manoeuvres of 1938 to be too clumsy and unwieldy. Accordingly, the following changes were made in 1939.

1939.

A division was now made into Nebelwerfer batteries and gas decontamination batteries. This new set up at the beginning of the year consisted of five Nebelwerfer batteries and four decontamination batteries, and later on in the year this was increased to five decontamination batteries. The Nebelwerfer battery consisted of:-

Staff.
 Signal Section (wireless and telephone on overland transport with four-wheel drive).
 1-3 Troops, each with two sections of four and later three projectors.

Light column (for supply of ammunition).

The projector used was still the 10 cm. Nebelwerfer 35. The decontamination battery consisted of:-

Staff.
 Signal section (as above).
 1-3 Troops (equipped with a special truck on tractors, i.e. gas identification vehicle and medium and smaller decontamination vehicles).
 Light column (supply of decontamination material)
 Heavy column (the bulk contamination vehicles - the medium Sprühh - KW and transport vehicles for the containers of ground contamination).

According to this arrangement each decontamination battery could be used as well either for decontamination, or for ground contamination.

Several projector batteries and one decontamination battery took part in the campaign in Poland, the latter without ever being used.

1940.

Quite a number of projector batteries were used in the spring offensive in France. They proved themselves useful in many battles, but particularly so at river crossings. The decontamination batteries were never used for the purpose for which they had been trained.

Projector batteries were also sent to Norway.

The Nebelwerfer 40 was introduced in this year. It was a breach loader and attained a range of 6500 m. On account of its weight and angle of fire, it was never popular with the troops, and in a short time was removed from the equipment.

Towards the end of this year, a special Nebel regiment staff was formed so that projector batteries and decontamination batteries could be grouped together, for the sake of easier and more concerted control, into one regiment. As long as the Nebeltruppe was only used as a battery, the special staff were chiefly concerned only with unit training. Special regiments were only formed later. Each regiment was composed of two projector batteries (motorised) and one decontamination battery (motorised).

In autumn, an instructional battery was formed in Poland to instruct the other batteries (projector and decontamination) in the use of the heavy Wurfgerät 40. The Wurfgerät 40 consists of a wooden frame firmly anchored to the ground which can be altered at will by means of props, to shoot at any angle from 20°/45°. The packing cases containing the ammunition are placed on these frames and bolted on. The ammunition is shot out of its packing case. There was a 28 cm. HE projectile and a 32cm incendiary projector. The range for HE was 2200 m. and for incendiary 1950 m. The Wurfgerät were set up in parallel rows and fired electrically. By means of delay fuses it was so arranged that four projectiles could be fired from each frame in eight seconds. Each battery had forty-eight such frames and could fire, therefore, 192 projectiles in eight seconds. The scatter was considerable and was, on the average, about 400 m. in length by 200 m. wide. This weapon is therefore only suitable for area shoots, and is decidedly a "Schwerpunktswaffe".

1941.

At the beginning of this year, it was possible with the formation of special regimental staffs to form four regiments of three batteries each out of the eight Werfer batteries and five decontamination batteries, and the constructional battery for the heavy Wurfgerät.

In the spring campaign in the Balkans several Werfer batteries were used with success.

The greatest use was made of Nebeltruppe in the field during the campaign in Russia in June 1941. Most of the batteries were used for the forcing of the Bug crossing. An attack was also made on the citadel and central defence point of the defensive position of Brest Litowsk with the help of nine batteries of heavy Wurfgerät. The success of these troops and particularly of the heavy Wurfgerät was remarkable. For this attack on Brest Litowsk two of the decontamination batteries were equipped with heavy Wurfgerät. This increased equipment was left with these two batteries for further work during the Russian campaign and was used from time to time.

In August 1941 the five decontamination batteries (motorised) were finally equipped with the heavy Wurfgerät 40 and they held this equipment along with their decontamination equipment. In September 1941, the decontamination equipment was finally left with the reserve troops and the decontamination batteries were now only equipped with the heavy Wurfgerät.

Towards the end of 1941 the wooden frame of the heavy Wurfgerät 40 was replaced by an iron frame and fitted with an improved anchoring device. This apparatus was given the name - Heavy Wurfgerät 41.

To make up for the loss of the decontamination batteries for decontamination work, three road decontamination batteries were formed in the autumn of 1941. They were equipped with motor vehicles on which could be fitted an improvised spreader which could be made by the troops themselves. The store of Losantin was carried in drums on the vehicle, and the Losantin could be distributed in an even manner from the improvised distributor. The chief purpose of this battery was to deal with decontamination of transport immediately behind the front line.

1942.

At the beginning of this year there were in all -

Five Nebelwerfer regiments (equipped with 15 cm.
Nebelwerfer).

Two heavy Werfer regiments (equipped with Nebelwerfer
for 28/32 cm. ammunition).

One Mountain Werfer battery.

Three road decontamination batteries.

One Nebel instruction regiment.

These regiments were usually composed of three batteries, but one heavy Werfer regiment had only two batteries. For firing the 28/32 cm. ammunition an apparatus was introduced for firing 6 at a time in place of the heavy Wurferät 41. The 28 cm. HE or 32 cm. incendiary could be fired from this apparatus as required. For the firing of the smaller calibre, attachable rails could be fitted. In addition a 32 cm. Nebelwerfer with a range of 5600 m. was developed. It was expected gradually to replace the 28/32 cm. Werfer.

In this year the Panzer Werfer was also developed with ten tubes on a pivoted base which could be fitted to armoured vehicles. This Werfer had a remarkable rate of fire and on account of its mobility allowed a quick change-over of the firing point. For armoured pioneer companies an attachment was developed which enabled six 28 cm. HE or 32 cm. incendiary projectiles in their cases to be fitted to the side of mechanised transport and fired electrically. The attachment was fitted permanently to the sides of the M.T. and the angle of fire could be adjusted by means of a semi-circular plate fitted with a scale. These motorised projectors were used with particular success against defended villages and posts and against tank barriers. Towards the end of the year a special brigade staff was formed and used for the larger battles.

1943.

At the beginning of this year on account of the scarcity of Werfer transport and the big requirements for the use of Werfer batteries, all the special vehicles for decontamination and bulk contamination were changed over to Werfer vehicles.

In place of the no longer used Sprüh KW and the medium decontamination vehicles, improvised decontamination and bulk contamination vehicles were made from transport of the type "Maultier". In this year Panzer Werfer troops each with 10 x 15 cm. tubes on a pivoting base mounted on A.F.V.'s were formed. Each troop had four to six such vehicles. During the year the brigade staff for Nebeltruppe was finally formed as well as Werfer brigades, the brigade having to begin with two regiments, one light and one heavy.

1944.

In the spring of this year there were four Nebelwerfer and one Mountain Werfer batteries. During the year the Nebeltruppe was doubled in size and by the end of the year consisted of eight Werfer brigades which were employed on all fronts. The ninth brigade was being formed at the end of the year. The equipment of these brigades was 15 cm. Nebelwerfer for the light batteries and 21 cm. and 30 cm. Nebelwerfer for the heavy batteries.

During the year the road decontamination batteries were disbanded and the personnel used for the reforming of the Werfer regiments.

1945.

Three further brigades should have been formed during this year, but at the cessation of hostilities, only the staff had been formed.

The projector regiments were also to have been equipped with the 35 cm. Nebelwerfer. This apparatus was to have been capable of firing two different projectiles. The ammunition with a short propellant charge at a maximum range of 3500 m. and the ammunition with the long propellant charge at a maximum range of 10,000 m.

Further Planning

For the future it was planned to go over to even bigger calibres with a still greater maximum range, but above all attention was to be given to the rather big scatter of the weapon and to improve this by alteration of the projector frame, and more particularly by paying attention to the ballistics of the ammunition.

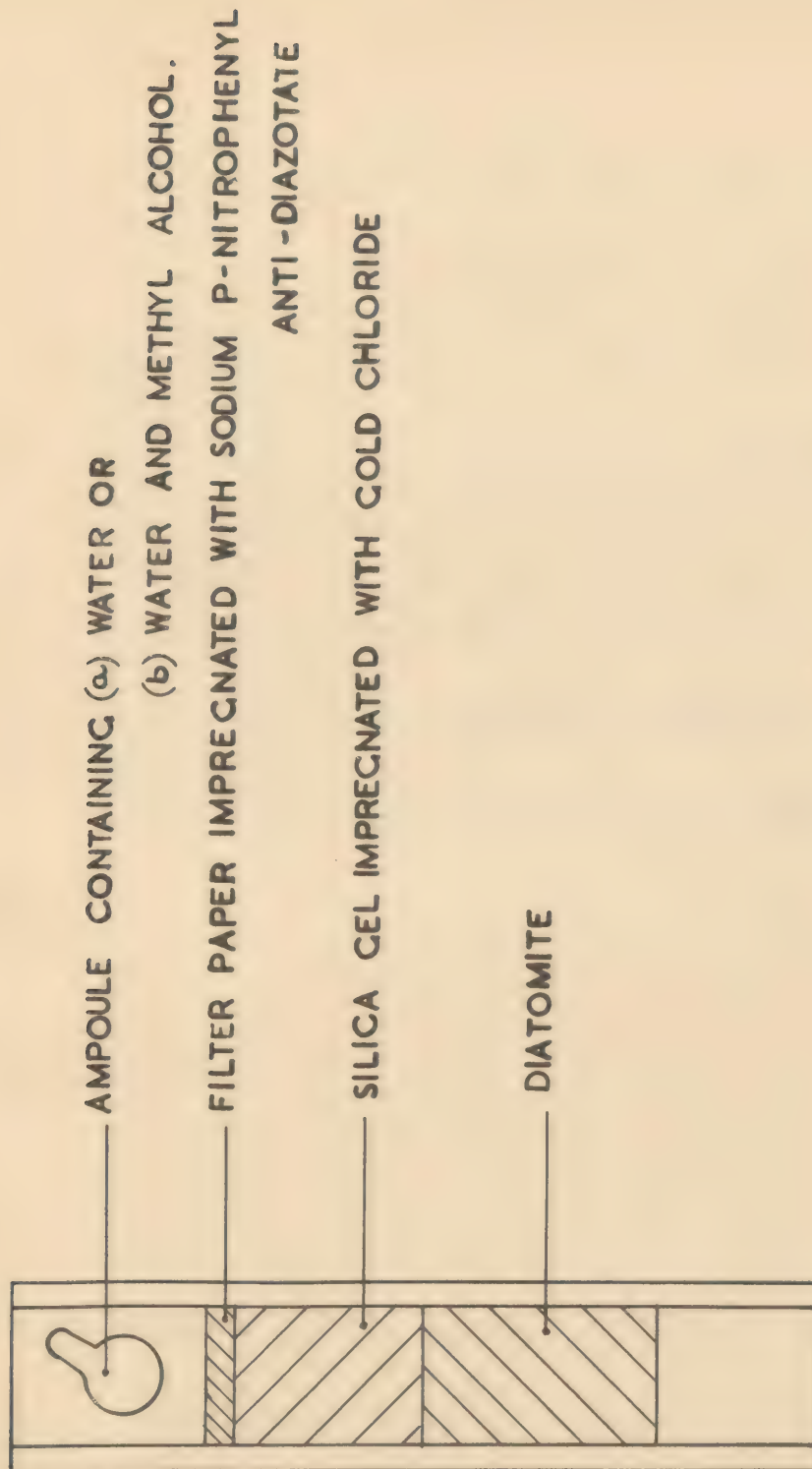
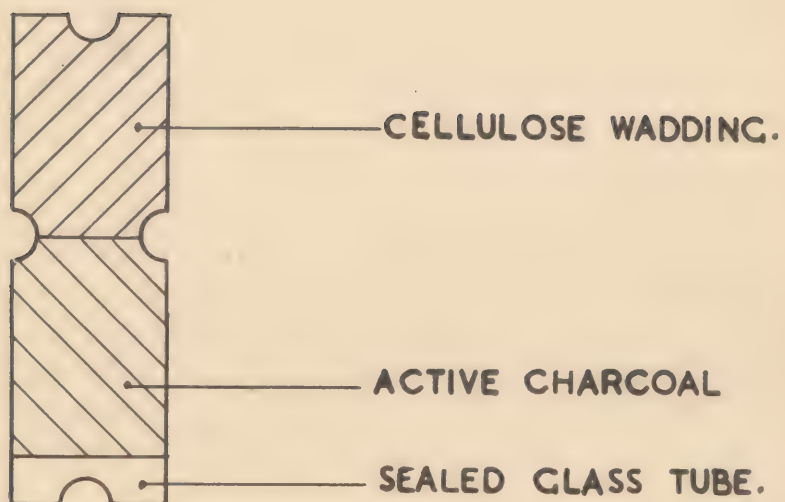


FIG: I







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